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ABSTRACT

As the eighth lesson of the Articulated Multimedia Physics Course, instructional materials are presented in this study guide with relation to the laws of motion. The topics are concerned with the relation between force, dynamic properties of objects, and Newton's laws. The content is arranged in scrambled form, and the use of matrix transparencies is required for students to control their learning activities. Students are asked to use magnetic tape playback, instructional tapes, and single concept films at the appropriate place in conjunction with the worksheet. Included are a homework problem set and illustrations for explanation purposes. Related documents are SE 015 963 through SE 015 977. (CC)

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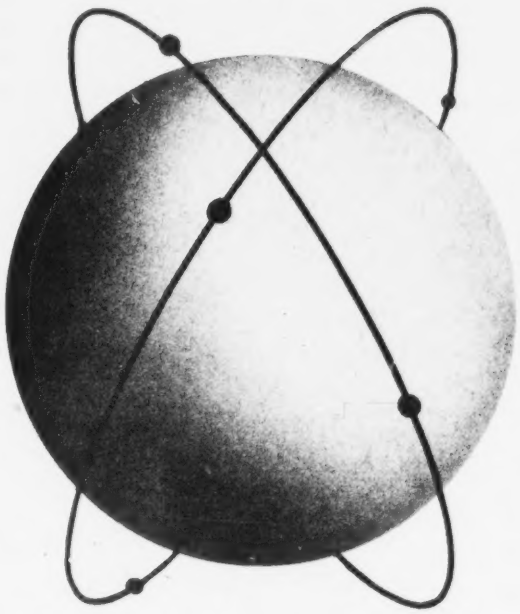
ARTICULATED MULTIMEDIA PHYSICS



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LESSON 8

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ARTICULATED MULTIMEDIA PHYSICS

Lesson Number 8

THE LAWS OF MOTION

IMPORTANT: Your attention is again called to the fact that this is not an ordinary book. It's pages are scrambled in such a way that it cannot be read or studied by turning the pages in the ordinary sequence. To serve properly as the guiding element in the Articulated Multimedia Physics Course, this Study Guide must be used in conjunction with a Program Control equipped with the appropriate matrix transparency for this Lesson. In addition, every Lesson requires the availability of a magnetic tape playback and the appropriate cartridge of instructional tape to be used, as signaled by the Study Guide, in conjunction with the Worksheets that appear in the blue appendix section at the end of the book. Many of the lesson Study Guides also call for viewing a single concept film at an indicated place in the work. These films are individually viewed by the student using a special projector and screen; arrangements are made and instructions are given for synchronizing the tape playback and the film in each case.

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In Lesson 7, Combining Forces, we learned how forces acting on a particle can be combined to determine net force, and how we can determine the components of a given force in specific directions. In some of our examples it was apparent that the net force would cause the particle to change its motion. If a particle is at rest, then the action of net force of any value will cause it to move out of the state of rest; if the particle is already in motion, a net force brought to bear on it may increase or decrease its speed, or may change its direction. Many of our ideas were based on the condition of equilibrium in which the net force on the particle is zero.

This entire area is often called Statics. Freely defined, the word "static" means unmoving. By referring to the subject we have just finished as Statics, we imply that we are interested specifically in equilibrium conditions rather than in the kind or amount of motion produced by the forces. By understanding the true meaning of equilibrium, we pave the way for a deeper comprehension of the material in this and in succeeding lessons.

Our universe is not static, however. The small and big events of our daily lives are inseparably bound to various kinds of motion and the forces that produce them.

So we embark on the subject of Dynamics. Stated as simply as possible, Dynamics deals with the relation between force, the nature of the object on which it acts, and the resulting change in motion.

Please go on to page 2.

Throughout recorded history, and probably before that, man has endeavored to understand the causes of motion. The early Greeks considered the state of rest to be the "natural" one. A body moves, they thought, only as long as a force acts on it. Remove the force, and the motion stops. Yet plenty of evidence exists to prove that objects tend to keep moving even after the driving force is gone. You shoot an arrow from a bow; the force of the bent bow is applied only for an instant but the arrow travels on for a comparatively long time after that. Aristotle contrived an explanation for such residual motion by attributing to the air the ability to get behind the arrow and push it along.

Today we know this explanation is wrong. But many centuries of progress in thought stand between us and Aristotle. Man's understanding of motion did not blossom suddenly out of nowhere; it grew slowly through the years as one brilliant thinker after another contributed his share. Few people in our society have not heard of Galileo, Kepler, and Newton. In your own study of elementary science, you must have been impressed by the importance of each contribution to the growth of modern physics.

Most authorities would agree that Sir Isaac Newton's work was the most important of all. The poet Alexander Pope, a contemporary of Newton, had this to say about him:

"Nature and Nature's Laws lay hid in night:
God said, Let Newton be: and all was light."

Please go on to page 3.

It is said that Edmund Halley, the astronomer after whom the famous comet was named, was instrumental in persuading Newton to publish his single most important work, the "Principia." Halley's opinion of Newton is succinctly given in this line:

"Nearer to the gods no mortal may approach."

With the history of science spread out before us, we in the 20th century can view his work in a more accurate perspective. Although our view of Newton's genius is not dimmed by this perspective, we feel inclined to agree with Newton's own estimate of himself and of his predecessors:

"If I have seen farther than the others, it is because I have stood on the shoulders of giants."

In this lesson, you will become acquainted with "giant steps" made by this great man in the field of Dynamics. We hope that you will appreciate the marvelous clarity and simplicity of Newton's discoveries about our world.

Please go on to page 4.

Resting on the table before you is this Study Guide, a Program Control, a notebook, a pencil, and probably several drawing tools. They are examples of matter in different forms.

Suppose that one or more of these material objects were to slowly rise from the table of its own volition, hover in the air overhead for a moment, and then fly out of an open window. What would your reaction be?

We guess that, after your initial astonishment at this seemingly, supernatural occurrence, thoughts like these would run through your mind: "It's a hallucination, an illusion, or maybe I'm asleep and dreaming. Things like this just don't happen here or anywhere else on Earth."

The normal reaction of a student, as distinguished from that of a superstitious savage, can of course be attributed to previous education. Your learning and experience in the world combine to tell you that things like this don't happen for which of the following reasons?

(1)

A A device like the Program Control is much too heavy to start moving by itself.

B Matter does not change its motion unless an unbalanced force acts on it.

C A body that has weight must be lifted to make it move.

YOUR ANSWER --- A

You have either forgotten that velocity is a vector quantity or else you have been careless.

Refer to Figure 3 on page 17. True, the speed of the bus is constant. But as it rounds the curve in the road from B to C, its direction of motion is gradually changing from north toward the east. When either the magnitude of a vector or its direction changes, then the quantity it represents cannot be termed constant.

This is one of the most important ideas in dynamics. A moving object may have a constant speed, but its velocity is constant only if its path is a straight line. A change in direction means a change in velocity.

Please return to page 17. Choose another answer.

YOUR ANSWER --- C

This answer selection was incorrect; the second statement is false.

Inertia is measured by mass only. There is a strong tendency among students to confuse inertia with things like momentum and energy, topics we have not yet studied. It is true that speed of motion has a great deal to do with determining the momentum or energy of a moving body, but these properties are different from inertia in concept and in manner of measurement.

Inertia may be further described as the resistance offered by a body against a change in speed or direction. Inertia may keep a body from moving, as well as keep it in steady motion. As such, only the mass of the body governs inertia.

Please return to page 14 and select the right answer.

YOUR ANSWER --- C

This choice is incorrect.

To prove it, we shall show that <u>one</u> of the equations is wrong. This is not to say that the other is necessarily correct. We'll leave that to your judgement.

Answer (4) is incorrect. If a is inversely proportional to m, then the mathematical expression must show that the <u>product</u> of a and m is a constant. Well, let's see:

$$\text{If } a = m/k$$

then we can transpose the k to the left side and a to the right where it is in the denominator. Thus,

$$k = m/a$$

which states that the ratio of m to a equals constant k. But that doesn't describe an inverse proportion, does it? A constant ratio defines a direct proportion; hence (4) is incorrect.

Please return to page 80. Choose a better answer.

YOUR ANSWER --- D

There are 2,000 lb in one ton. Since the pound in our work is considered solely as a force or weight unit, the ton must also be used only as a force or weight unit.

In short, you cannot specify the mass of anything in tons if you intend to be consistent with the English system we are using.

Please return to page 27. Choose a better answer.

YOUR ANSWER --- B

This answer indicates some thoughtlessness.

The friction between the soles of your shoes and the floor of the bus produces a horizontal force on the lower part of your body directed toward the north. This causes the lower part of your body to move suddenly toward the north, leaving the rest of you behind as a result of your body's inertia.

Now imagine that you are looking at a poster on the inside of the bus when this happens. Your body will remain stationary while the poster begins to move in the direction of the bus's motion, that is, toward the north. With respect to your body, then, the poster will take off in a northerly direction. Relatively speaking, what visual impression would you get as to the direction in which the upper portion of your body is moving with respect to the poster?

Please return to page 68. The other answer is correct, of course.

YOUR ANSWER --- B

You are correct. We solve for the numerical value of k by ignoring the units and using only the numbers.

$$1 \text{ m/sec}^2 = k \times \frac{1 \text{ nt}}{1 \text{ kg}}$$

Thus: $1 = k \times \frac{1}{1}$, wherein k must equal unity.

Because we defined the newton in terms of m/sec^2 and kg, k becomes unity and therefore drops out of the equation altogether. This means that just as long as we measure acceleration (a) in m/sec^2, mass (m) in kg, and force (F) in newtons, we never have to worry about k or its value again.

As a result of this, we can now write Newton's Second Law as follows:

$$\boxed{a = \frac{F}{m}}$$

where: F is in newtons (nt)
m is in kilograms (kg)
a is in meters per second per second (m/sec^2)

Many textbooks give the final mathematical equation for Newton's Second Law in a form where F is alone on the left side of the equals sign.

You can work this form out. Solve the framed expression for F in terms of a and m. Which equation below matches your solution?

(23)

A $F = ma$

B $F = a/m$

C $F = m/a$

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- B

We asked you what you thought would happen under these circumstances. In other words, we want you to make an intelligent guess based on similar experiences you may have had.

Think of the last time you pulled someone along on a sled or wagon. If you wanted to get the sled up to high speed in a hurry, didn't you dig in with your toes and pull on the rope for all you were worth? Well, "getting the sled up to high speed in a hurry" is an offhand way of saying that you were causing a large acceleration. And what size force did you need to exert in order to realize this large acceleration?

At some other time, when there was no need for large acceleration, a much smaller force might have been exerted on the rope to get the sled going.

Based on these everyday events in your life, you should be able to choose the right answer to the original question.

Please return to page 100 and select the best answer.

YOUR ANSWER --- C

Surely you have met situations in your daily life which should help you arrive at the right answer to this question. Make use of these experiences; then your "guess" will not be a guess at all!

What are we seeking in asking the question: "Which acceleration, a_1 or a_2, has the larger magnitude, or are they the same"? We merely want to know the effect of mass on acceleration.

As you walk down the street, you see a small pebble on the pavement. You don't hesitate to kick it out of the way with the toe of your shoe. Perhaps you think, "The pebble is small; therefore it is light in weight. I won't hurt my foot if I kick it." From this moment on, please forget about weight in situations of this sort. A kicked pebble moves horizontally so that gravity contributes nothing to oppose the force you apply. So it is the mass of the pebble that should concern you. You know that a small unbalanced force applied to it will accelerate it out of your way. But suppose you apply the same small unbalanced force to a bowling ball? How would its acceleration compare with that of the pebble?

You should have the information you need now. Please return to page 137 and select the right answer.

YOUR ANSWER --- C

You are correct. Just as long as we continue to define mass as the quantity of matter in a body, this statement is quite true. Conversely, anything we designate as matter must have mass.

None of our experimental observations, whether of natural phenomena on the earth or in space, has ever given evidence that a change in the motion of a mass can ever be accomplished without the application of an unbalanced force. Until proven otherwise, then, we accept this as a "law" of nature. It is a property of matter at rest to stay just where it is unless an unbalanced force acts on it. Similarly, it is a property of matter moving with uniform velocity to remain in motion with exactly the same speed and in the same direction unless acted upon by an unbalanced force. This property is called inertia.

The mass of a body determines how much inertia it will have when at rest or in motion. For this reason, mass is often called the measure of the inertia of a body Mass and inertia, as concepts, are virtually synonymous. To keep these ideas straight in your mind think of inertia as a property of matter and mass as a numerical way of measuring inertia.

Read the statements below. They may both be true or only one of them may be true. Make your selection according to instructions.

(3)

A A very massive body has a correspondingly large inertia. (This is the only true statement.)

B The inertia of a moving body depends to some extent on its speed. (This is the only true statement.)

C Both statements are true.

YOUR ANSWER --- B

There is something wrong with your notes. Furthermore, even without notes, you should remember the test for a direct proportion. You should be able to answer this kind of question almost without thinking at this stage. Please correct your notes:

> If a table of values for two quantities exhibits a constant ratio, then the quantities are directly proportional.
>
> If a table of values for two quantities exhibits a constant product, then the quantities are inversely proportional.

Now return to page 65 and that last table of values for mass and acceleration and determine whether there is a constant ratio or a constant product. Then select the right answer.

YOUR ANSWER --- B

Your memory is slipping. We are not talking about velocity.

We never proved this point. This may explain why you failed to remember it. It is always more difficult to recall isolated facts when we have not been given logical reasons for them.

At the time we presented this motion, we had not covered enough physics to offer any kind of logical explanation, so we simply told you about acceleration of a body in free-fall.

Please return to page 25. The alternative answer is correct.

YOUR ANSWER --- C

You are correct. The bus moves with uniform velocity with respect to the ground and so do you. Your body, therefore, is in dynamic equilibrium with respect to the ground and in static equilibrium with respect to the bus.

Next, we shall analyze the effect of inertia upon your body when the bus rounds a curve. Refer to Figure 3.

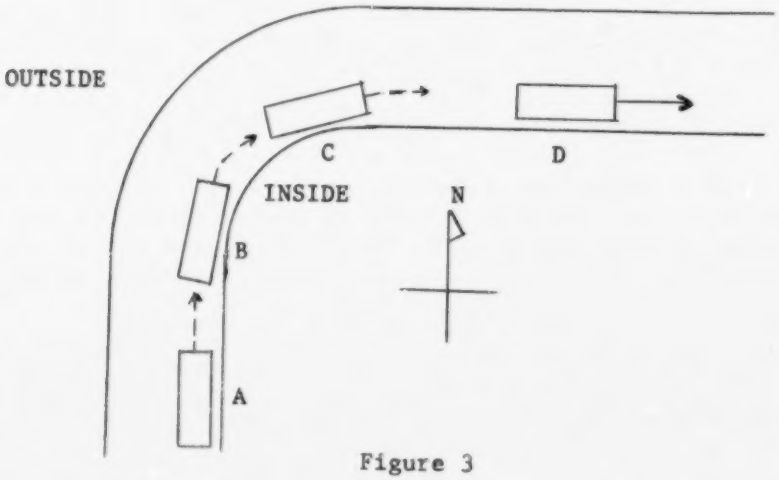


Figure 3

As you see, the bus traveled north at the start of our analysis. Its velocity was uniform at position A. Now, maintaining constant speed, the bus reaches point B where it begins to round the curve toward the east.

Does the bus move with uniform velocity from B to C?
(Remember, its speed is constant throughout the trip shown in Figure 3.)

(7)

A Yes.

B No.

C I am not sure.

YOUR ANSWER --- C

You are correct. Acceleration is directly proportional to unbalanced force; therefore an INCREASE in F will produce an INCREASE in a.

In all our past lessons we have used the pound as a unit of force principally because our daily lives are almost exclusively bound up with this unit. This is indeed unfortunate. As it happens, in the English system the pound has been used as both a mass unit and a force unit; as the system grew in its applications, the confusion caused by this ambiguity grew with it and has persisted right up to the present. This is one of the reasons why physicists have virtually abandoned the English system altogether and have replaced it with the MKS system or the Meter-Kilogram-Second system. Because the MKS system has been scientifically constructed to reduce unit confusion to a minimum, we shall use it exclusively from now on.

We do not mean to imply that we shall never mention the English system again; this would be foolhardy because it would remove the familiar "foundation" you need to help you get the "feel" of the new units. But our quantitative thinking and our problem-solving will be based on the MKS system.

Please go on to page 19.

Just to review for a moment: in MKS, the unit of length is the meter and the unit of time is the second.

What does a kilogram measure?

(21)

A Weight.

B Mass.

C Force.

YOUR ANSWER --- A

This is not so.

It is true that the application of the force causes the body to accelerate. If it was at rest in the first place, it will begin to move in the direction of the applied force; if it was moving in the first place, and the force is applied in the direction of its initial motion, the body will pick up additional speed; if the force is oppositely directed, the body will slow down.

What condition prevails when the force is removed? Now there are no unbalanced forces on the body, so it must be in a state of dynamic equilibrium.

When a body is in dynamic equilibrium, what kind of motion does it possess?

(10)

A It moves with uniform velocity.

B I cannot tell without more data.

YOUR ANSWER --- B

You are making up your own rules.

There are ABSOLUTELY NO EXCEPTIONS to the rule that requires the units on one side of an equation to be exactly the same as those on the other side.

Give it some more thought. Remember that the newton was defined as the force that could give a 1 kg mass an acceleration of 1 m/sec^2.

Please return to page 48 and look over the other answers before making another choice.

YOUR ANSWER --- B

Actual measurement would show that the force exerted by the boy and the reaction force--that exerted by the box on the boy--are exactly the same in magnitude.

This is a point that must be accepted because we have so much experimental evidence to prove it. If you have a spring balance, you can do a simple experiment of your own to prove it, as we shall explain later.

Please return to page 54 and select a better answer.

YOUR ANSWER --- A

You've made an error. Suppose we find it by going through the operation involving the proposition we discussed; that is let q = a, b = F, c = 1/m. Then substitute in the proposition.

In the proposition	For the Second Law
If q = kb and q = kc, then q = kbc.	Let q = a = kF and a = k/m, so a = k(F x $\frac{1}{m}$).

Now ask yourself: does the product k(F x $\frac{1}{m}$) reduce to the answer given above? Obviously not.

Please return to page 70. You now have enough information to recognize the right answer.

YOUR ANSWER --- C

You're absolutely right. Here are the solutions:

1. $F = ma$; hence $m = F/a$. Thus, $m = \frac{30 \text{ nt}}{10 \text{ m/sec}^2} = 3.0 \text{ kg}$.

2. $F = ma$; hence $F = 5.2 \times 10^{-2} \text{ kg} \times 1.1 \times 10^{2} \text{ m/sec}^2$
   $= 5.2 \times 1.1 \times 10^{-2} \times 10^{2}$ newtons
   $= \underline{5.7}\ \underline{\text{nt}}$.

3. $1.5 \times 10^{3} \text{ cm/sec}^2 = 15 \text{ m/sec}^2$ and $1.0 \times 10^{3} \text{ g} = 1.0 \text{ kg}$
   $F = ma$; hence $F = 15 \text{ m/sec}^2 \times 1.0 \text{ kg} = \underline{15}\ \underline{\text{nt}}$.

4. $a = F/m$; hence $a = \frac{144 \text{ nt}}{12 \text{ kg}} = 12 \text{ m/sec}^2$.

5. First find a: $a = F/m = \frac{5.0 \text{ nt}}{10 \text{ kg}} = 0.5 \text{ m/sec}^2$

   Next find v: $v = at = 0.5 \text{ m/sec}^2 \times 8 \text{ sec} = \underline{4.0}\ \underline{\text{m/sec}}$.

Please go on to page 25.

We turn our attention now to a special form of Newton's Second Law which has particular reference to the weight and the free-fall acceleration of a body on the Earth, specifically in the vicinity of 40° N. latitude.

We are going to make use of two distinct facts which you already know. The first is that the weight of a body is a true force which arises as a result of the gravitational attraction between the Earth and the object. This implies that when we speak of the weight of an object (on Earth and at the latitude specified), this weight may replace the force term in the Second Law. Thus, for these conditions, $w = F$ where w = the weight of the body.

The second fact as presented in a previous lesson concerns acceleration due to gravity. Think back. Does a body in free-fall near the surface of the Earth accelerate uniformly or non-uniformly?

(28)

A It accelerates uniformly.

B It accelerates non-uniformly.

YOUR ANSWER --- A

No, the smoother the paper, the better the chance for success.

The idea is this: as the paper is jerked from under the object, it must be free to move without exerting any significant force on the ball or egg. If the paper is smooth, the friction between it and the object will be small so that as the paper goes into motion, the force you exert will not be transmitted to the object. Hence, the object will remain at rest.

It is for this very reason that an amateur should never try to jerk a tablecloth out from under a wineglass!

Please return to page 85. You should know the answer now.

YOUR ANSWER --- A

You are correct. On the moon, $w = mg'$, where $g' = 1/6\ g$. So $g' = 1/6 \times 9.8\ m/sec^2 = 1.6\ m/sec^2$, approximately. Thus the weight on the moon is $w_m = m \times 1.6\ m/sec^2$ while the weight of the same object having the same mass on the Earth is $w_e = m \times 9.8\ m/sec^2$. Obviously, the weight on the moon would then be about 1/6 of the object's weight on earth.

Next, let us combine some of our operations. The example that follows is handled in several steps. Follow each one carefully, please! Copy the problem on a piece of paper before you continue.

A 5-ton spaceship is on its way to Jupiter. Somewhere along the route, its retro rockets are to apply a force that will cause a deceleration of $100\ m/sec^2$ to allow the spaceship to land. What magnitude and direction must this force have?

The problem speaks of a 5-ton spaceship. Using plain logic and perhaps a bit of intuition, answer this question first: When we specify a 5-ton spaceship, which one of the following do we mean?

(32)

A Its mass is 5 tons anywhere in the universe.

B Its weight is 5 tons anywhere in the universe.

C Its weight is 5 tons on Earth.

D Its mass is 5 tons on Earth.

YOUR ANSWER --- C

No. Sorry, but this is not right.

Unless we examine your work, it is very difficult to analyze your errors. This is something you must do for yourself after you have had a chance to examine the correct solution. But, for the present, you must not give up. Follow the additional hints below and do your best to arrive at the right answer.

This problem is approached by determining the individual masses with the help of $m = F/a$.

The total combined mass is then obtained by adding the individual masses. If you left these in fractional form, as was suggested, perhaps your error lay in the addition of the fractions.

The acceleration of the combined mass is then determined by means of $a = F/m$. The force throughout the problem is 5 newtons.

PLEASE DON'T GUESS AT THE ANSWER. In scientific studies, you can be sure there is a reason for everything. Try the problem again. Please return to page 44 and select the right answer.

YOUR ANSWER --- C

You are correct. The statement "For every force there is an equal and opposite force" leads to a picture that shows balanced forces which leave a single particle in equilibrium. But you know that a large force must cause the particle to move out of its rest state; hence the picture does not agree with experimental fact. The second statement, "Every action has an equal and opposite reaction," leads to the same fallacious picture.

You might say, "Well, then, apply a larger force to the particle; that will surely change its motion." According to the statement, or at least the interpretation we might place upon it due to its inadequacy, even this wouldn't produce motion. See Figure 10. The reaction force, F', would simply increase equally and the result would still be equilibrium.

Figure 10

Following this line of reasoning, you must conclude that no body anywhere in the universe could ever have its motion changed because it would be physically impossible to exert an unbalanced force on it. Since it leads to a clearly ridiculous conclusion, we must rephrase the statement of the "action and reaction" law.

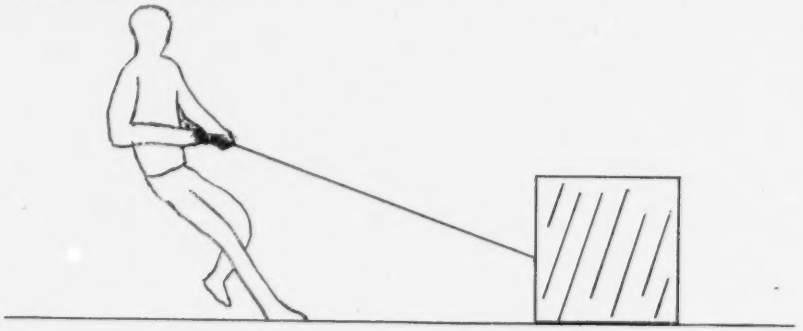


Figure 11

Refer to Figure 11. A boy applies a pulling force on a box, causing the box to move toward him. How many bodies are involved in this action?

(37)

A One body.

B Two bodies.

YOUR ANSWER --- D

This choice is incorrect.

To prove it, we shall show that one of the equations is wrong. This is not to say that the other is necessarily correct. We'll leave that to your judgement.

Answer (1) is incorrect. If a is inversely proportional to m, then the mathematical expression must show that the product of a and m is a constant. Well, let's see:

If $a = km$

then we can transpose the m to the left side, placing it in the denominator. This yields:

$$a/m = k$$

which states that the ratio of a to m is a constant. But that doesn't describe an inverse proportion, does it? A constant ratio defines a direct proportion; hence (1) is incorrect.

Please return to page 80. Choose an alternative answer.

YOUR ANSWER --- B

You are correct. The constant ratio becomes very apparent if you actually work it out:

$$\frac{2}{0.4} = 5$$

$$\frac{4}{0.8} = 5$$

$$\frac{6}{1.2} = 5$$

$$\frac{8}{1.6} = 5$$

$$\frac{10}{2.0} = 5$$

CONSTANT RATIO

The next step should be easy for you now.

If a series of corresponding values of two variables forms a constant ratio, what kind of proportionality is indicated?

Think carefully before you fix the answer in mind; then go on to page 32.

CORRECT ANSWER: If a series of corresponding values of two variables forms a constant ratio, then the variables are directly proportional to each other.

If the answer you had in mind for the question above was inverse proportion, this indicates that you need still further review of proportions to reestablish in your mind the fact that:

A constant ratio means a direct proportion.
A constant product means an inverse proportion.

If your answer was wrong, please go over your notes on proportions very carefully until it all comes back to you. Then try not to forget again.

You would do well to remember something like this:

DIRECT proportion: If one variable goes UP, the other also goes UP.

INVERSE proportion: If one variable goes UP, the other goes DOWN.

We will now have you go back to the question that started all this. Please return to page 50.

YOUR ANSWER --- B

No, this answer is quite incorrect. The first part of the statement contains a bad conceptual error and the second part does not logically follow.

The bus is moving with uniform motion, changing neither its speed nor its direction. You are, to all intents and purposes, a part of the bus, so you, too, must be moving with uniform velocity. But a body moving with uniform velocity is in dynamic equilibrium and cannot have any unbalanced forces acting on it. If, as the answer above states, there is a force exerted on you by the floor of the bus, you could not be in equilibrium at all since this force would be unbalanced. This is contradictory.

Secondly, "any forces you exert will move you just where you want to go" not only doesn't follow, but is also a misstatement. You cannot, for example, rise into the air by flapping your arms like a bird; you are exerting a force on the air in this case but it doesn't move you where you want to go.

Please return to page 77 and select a better answer.

YOUR ANSWER --- C

This is incorrect. We have said that doubling the force causes the acceleration to double; tripling the force causes the acceleration to triple; quadrupling the force causes the acceleration to quadruple; etc.

O.K. For simplicity, let us say that when the initial force is F_1, the acceleration is 7 units. (This value for $\underline{a}$ is chosen completely at random.) Therefore:

F_1 yields an acceleration of 7 units.

Since F_2 is double F_1, and we know that the acceleration doubles too, this permits us to write:

$F_2 = 2F_1$ which yields an acceleration of 14 units.

Similarly for F_3 and F_4:

$F_3 = 3F_1$ which yields an acceleration of 21 units.
$F_4 = 4F_1$ which yields an acceleration of 28 units.

That there is a constant ratio present becomes evident from this:

$$\frac{F_1}{7} = \frac{1}{7F_1}$$

$$\frac{2F_1}{14} = \frac{1}{7F_1}$$

$$\frac{3F_1}{21} = \frac{1}{7F_1}$$

and so on.

Is a proportionality implied? Return to page 50 and try again.

YOUR ANSWER --- C

No, it doesn't.

If you think back carefully, you will remember that we have never measured force in the mks system at all. All our force problems in composition and resolution of vectors used pounds. Actually, we have never mentioned or implied the use of the mks system in any kind of force situation.

Perhaps this will help you: to give you the idea of the size of a kilogram, we told you that a kilogram of matter exerts a force of about 2.2 lb in the vicinity of 40^{o} N. latitude. This is just another way of saying that 1 kilogram of matter weighs about 2.2 lb at that latitude. Weight is caused by gravitational force between two bodies. Although it is true that weight is a force, in this case we were measuring the force in pounds, <u>not</u> in kilograms.

Please return to page 19 and choose the right answer.

YOUR ANSWER --- A

Your answer implies that, if the Program Control machine were very light in weight, it could start to move of its own volition without help from the outside.

This, of course, is quite untrue. Think of the lightest thing in the world that you can see with the unaided eye. Perhaps a fluff of thistledown or a delicate feather or a puff of smoke. Now picture any of these in an evacuated chamber where it is protected from the stir of breezes and from gravity and other forces. It would not begin to move until some kind of force was applied to it.

Very often, an answer such as the one above has a ring of truth, but on further analysis it breaks down into vagueness or ambiguity. We must try to avoid this kind of fuzzy thinking.

Please return to page 4. One of the other answers is much better. Pick it out.

YOUR ANSWER --- A

You probably had a feeling that this answer was wrong when you chose it. But we are all creatures of habit. It is so habitual for you to speak of weight in pounds that you do so without thinking. This is a habit you must lose! Weights and measures from the layman's world must not be allowed to intrude into science when they do not fit the facts.

Since kilograms and meters/second/second are MKS units, any equation in which these units appear must also give the weight in MKS units.

Please return to page 73 and select a more fitting answer.

YOUR ANSWER --- A

This is incorrect.

Please return to page 106 and select another answer.

YOUR ANSWER --- C

Why should any force greater than 5 nt act in this system? Where would it originate? (Remember that the balance is weightless.) The only other force besides the applied force that is present is the reaction force. In accordance with the Third Law, the reaction force has the same magnitude as the applied force.

Refer to Figure 13 on page 128. The weight exerts a force of 5 nt on the spring of the balance. Call the weight Body A and the spring Body B. So, Body A applies a force of 5 nt to Body B. Now, what must Body B do?

Please return to page 128. You should be able to select the right answer.

YOUR ANSWER --- A

Sometimes this is true, but just as often it is not true. Some examples will help.

Suppose we pour some water into a cup until it is half-full. The water which occupies a certain space and is composed of matter, may be called a "body." Now we add water until the cup is full. The space occupied is now about twice as great, the amount of matter is about twice as great, and hence the mass of the water has just about doubled. In this case, the statement is true.

Now refer to Figure 1. Here in A, we see two glass vessels consisting of thin glass bulbs connected to glass tubes of small diameter or fine bore. We start our experiment by filling both tubes to exactly the same level. In each, therefore, there is the same amount of matter, the same space occupied, and the same amount of mass.

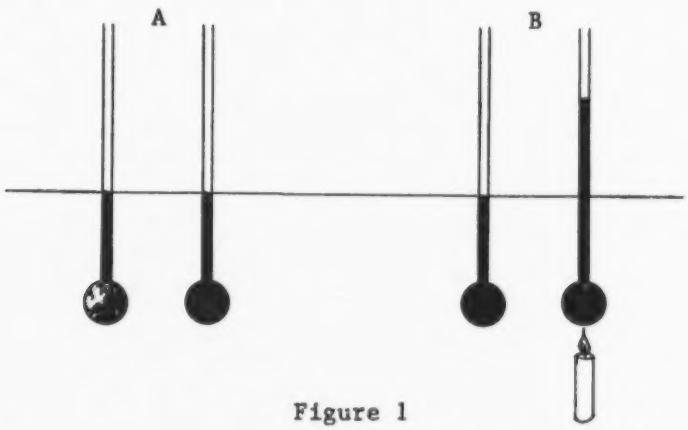


Figure 1

Now we heat one of the glass bulbs. The water in the bulb expands, causing the level of the liquid to rise (see Figure 1B.). We have not added any water; hence the quantity of matter has not changed, so that the mass must have remained the same. Yet the water now occupies more space. Thus, space occupied is not a criterion for judging mass in all cases.

Please return to page 131. You can find a better answer.

YOUR ANSWER --- B

Your algebra leaves something to be desired!

You're starting with $a = F/m$. You want F alone on one side of the equation.

Try multiplying both sides of the equation by m in order to cancel out the m which appears as a denominator on the right side of the equation. When you get F alone on the right, you can exchange it with the expression on the left and so get F on the left.

Please return to page 10. Work out the right form and pick the the appropriate answer.

YOUR ANSWER --- B

You have all the data you need!

By definition, a body in dynamic equilibrium has no unbalanced force or forces acting on it. Under these conditions, the body will NOT

(a) speed up
(b) slow down
(c) change direction

How do you describe this kind of motion? What other data could you possibly need?

Please return to page 20. The other alternative is the right answer, of course.

YOUR ANSWER --- C

You are correct. Since the pound is a force unit in the English system we are using, then the ton must also be a force unit. (Another type of English system bases its measurements on the pound as a unit of mass, but this system is considered obsolete by most authorities.)

The spaceship weighs 5 tons on Earth. Looking ahead, as we often must do in problem-solving, we realize that we will need to know the mass of the ship in MKS units. So, we'll convert the 5 tons to pounds first:

$$5 \text{ tons} \times 2{,}000 \text{ lb/ton} = 10{,}000 \text{ lb}$$

Thus, the spaceship weighs 10,000 lb. Next, we had better convert this weight into newtons.

With the help of your notes, convert 10,000 lb to newtons. Write your answer on your workpaper.

Turn to page 104 to check your answer with ours.

On the next problem, which is of a somewhat different type, we'll provide you with a hint or two. But we want you to do the actual calculations by yourself. Copy the problem before you begin.

A force of 5 newtons gives a mass m_1 an acceleration of 8 m/sec^2. The same force applied to a mass m_2 produces an acceleration of 24 m/sec^2. Suppose the two masses were now fastened together and the force of 5 newtons applied to the combination. What acceleration of the combined mass would you expect? (1 sig. fig.)

Hints: (1) Find the individual masses m_1 and m_2.
(2) Keep your intermediate answers in fractional form to simplify the arithmetic; that is, don't convert them to decimal numbers.

Which answer below is correct?

(34)

A The acceleration of the combined mass will be 3 m/sec^2.

B The acceleration of the combined mass will be 6 m/sec^2.

C The acceleration of the combined mass will be 9 m/sec^2.

YOUR ANSWER --- D

This is incorrect. There is an error in the third significant figure.

Please do the calculation again; then return to page 56 and select the right answer.

YOUR ANSWER --- C

Your hesitancy lies in the fact that you are still a bit confused about the accepted meaning of the word velocity and its relationship to speed.

By definition, velocity is a vector quantity. Therefore, to describe fully the velocity of any body, you must state precisely its magnitude and its direction. Once you do that, you have uniquely determined velocity for a particular object. For instance, if you say that the bus is traveling 45 mi/hr north, its velocity has one, and only one, value. Henceforth, you must remember that the direction of a body's motion is just as important in a statement of its velocity as its magnitude is.

Refer to Figure 3 on page 17. The bus is traveling north to point A. On reaching B, it starts to turn toward the east; between B and C it continues to alter its direction. Every succeeding second of its trip from B to C sees it moving in a new direction. So, although its speed is constant, its velocity is steadily changing from B to C because its direction is changing.

Please return to page 17. Choose the right answer.

YOUR ANSWER --- B

This statement is false.

Inertia is measured by mass only. There is a strong tendency among students to confuse inertia with things like momentum and energy, topics we have not yet studied. It is true that speed of motion has a great deal to do with determining the momentum or energy of a moving body, but these properties are different from inertia in concept and in manner of measurement.

Inertia may be further described as the resistance offered by a body against a change in speed or direction. Inertia may keep a body from moving, as well as keep it in steady motion. As such, only the mass of the body governs inertia.

Please return to page 14. Choose another answer.

YOUR ANSWER --- B

You are correct. Substituting in F = ma, we have

$$F = 45 \text{ kg} \times 3 \text{ m/sec}^2 = 135 \text{ newtons}$$

NOTEBOOK ENTRY
Lesson 8

Show this problem and its solution as an Example under 2(f).

Did something in this problem strike you as a little peculiar? How about the units? Look again at the solution above. On the left side, we have these units: kg x m/sec^2. When put in simplest form, this becomes kg-m/sec^2 or kilogram-meters per second per second. But on the right side in the solution we see only newtons. You have learned that an equation or a problem solution can be considered correct only if the units check; that is, if they are identical on each side of the equals sign. Now in this example we find that they are not the same, or at least they do not appear to be the same. What do you think this means?

The correct explanation is contained in one of the statements below. Which one is it?

(25)

A Units must check. The units for F = ma do not check. Therefore the equation is incomplete since the proper factor must be applied to make the units check.

B Units must check only when basic units are compared. The newton is not a basic unit, so it is not possible to check the units.

C The units do check. The newton is merely a more convenient name for kg-m/sec^2.

YOUR ANSWER --- D

This is incorrect.

Please return to page 106 and try again!

YOUR ANSWER --- A

You are correct, of course! You know from your everyday experience that if you increase the push or pull on a movable object, it will pick up speed faster; that is, it will experience a greater acceleration.

When we measure the actual acceleration of a given body due to different forces, we find a very simple relationship.

For example, when the force is doubled from 2 lb to 4 lb, in Figure 5 on page 100, actual measurement shows that the acceleration also doubles. Going further, tripling the force causes triple the original acceleration; quadrupling the force causes four times the original acceleration; and so on. This continues to be true only if the mass of the cart (we'll use m for mass) remains constant. In both drawings we have used m to designate the mass of the cart indicating that it doesn't change.

Using the simple relationship described above, what can you say about the way acceleration varies with force if mass is held constant?

(12)

A Acceleration is inversely proportional to the unbalanced force.

B Acceleration is directly proportional to the unbalanced force.

C No proportionality is implied at all.

CORRECT ANSWER: The mass of the spaceship is

$$m = \frac{w}{g} = \frac{45{,}000 \text{ nt}}{9.8 \frac{\text{m}}{\text{sec}^2}} = \underline{4{,}600 \text{ kg}}.$$

We can check this, since $\frac{10{,}000 \text{ lb}}{9.8 \frac{\text{m}}{\text{sec}^2}} = 4{,}600$ kg.

We now must find the retarding force required to give the spaceship (m = 4,600 kg) a deceleration of 100 m/sec^2. Of course, you remember that deceleration is negative acceleration. What we want, therefore, is the force required to produce an acceleration of -100 m/sec^2.

The rest is easy. From Newton's Second Law, we have:

$$F = ma = 4{,}600 \text{ kg} \times (-100 \text{ m/sec}^2)$$
$$F = -460{,}000 \text{ nt}$$
$$= \underline{-4.6 \times 10^5 \text{ nt}}$$

This is the whole answer. We were to determine both the magnitude and direction of the required force, and we have done so.

Which one of the statements below best describes the force F = -4.6×10^5 nt?

(33)

A The force is a minus quantity with a magnitude of 4.6×10^5 nt.

B The answer shows that we need a large negative force to do the job.

C The force required is 4.6×10^5 nt, directed oppositely to the motion of the spaceship.

YOUR ANSWER --- C

No, this answer isn't as good as it sounds. Don't grab at straws. Think it through a bit more completely.

Gravitation does not behave like light, at least not according to everyday evidence. Many material substances will stop light and prevent its transmission, but nothing has ever yet been discovered that will even reduce the force of gravity on a given mass in a given location.

Could the chair be exerting a force on your body?

Please return to page 93 and make another selection.

YOUR ANSWER --- B

You must have misread this answer because it is incorrect.

Since acceleration is directly proportional to the unbalanced force, how can you say that decreasing the force will give you increasing acceleration?

Furthermore, since acceleration is inversely proportional to mass, how could an increase in mass result in an increase in acceleration?

If proportions still give you trouble, you would do well to remember something like this:

DIRECT proportion: If one variable goes UP, the other also goes UP.

INVERSE proportion: If one variable goes UP, the other goes DOWN.

Please return to page 115 and select a better answer.

YOUR ANSWER --- B

You are correct. In any force action, there are always two bodies: (1) the one that applies the force and (2) the one to which the force is applied. The connecting rope is not, as a rule, taken into consideration; it is generally thought of as being weightless.

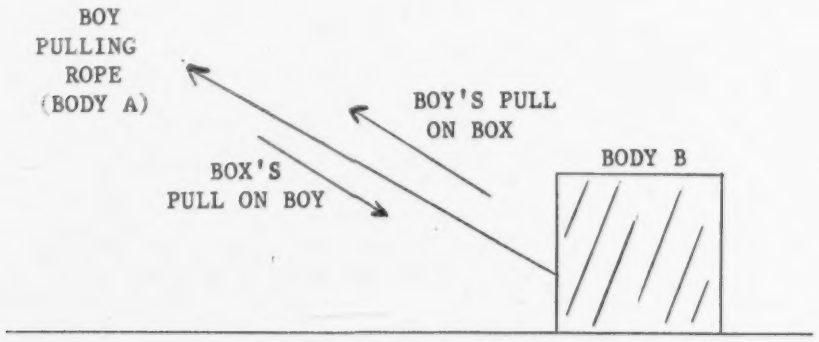


Figure 12

Refer now to Figure 12. The true situation is shown in this drawing. The boy (Body A) exerts a force on the box; the box reacts by exerting an equal force on the boy in the opposite direction. Here we again have two forces of equal magnitude pulling in opposite direction. But how different this is from our original conception! We want to see whether or not you can spot the significant difference, so select one of the statements below as the applicable description of the forces in the Diagram.

(38)

A The two forces are of equal magnitude, are applied to the same body, but are opposite in direction.

B The two forces are of unequal magnitude, are applied to different bodies, and are opposite in direction.

C The two forces are of equal magnitude, are applied to different bodies, and are opposite in direction.

YOUR ANSWER --- A

This choice is incorrect.

To prove this, we shall show that one of the equations is wrong. This is not to say that the other is necessarily correct. We'll leave that to your judgement.

Answer (1) is incorrect. If a is inversely proportional to m, then the mathematical expression must show that the product of a and m is constant. Well, let's see:

$$\text{If} \qquad a = km$$

then we can transpose the m to the left side, making it a denominator. This gives us:

$$a/m = k$$

which states that the ratio of a to m is a constant. But that doesn't describe an inverse proportion, does it? A constant ratio defines a direct proportion; hence (1) is incorrect.

Please return to page 80. Select a different answer.

YOUR ANSWER --- C

You are correct. If you saw this immediately, you're to be congratulated on your astuteness. Not many students do!

Look at it this way. Suppose you didn't know the unit for force in F = ma, but suppose you measured a mass in kilograms and determined its acceleration in meters/sec/sec. Then if you substituted in F = ma, you would obtain:

$$F = Y \text{ kg} \times Z \text{ m/sec}^2$$

Regardless of the numbers represented by Y and Z, you would know that the unit for force in this case is kg x m/sec^2 or $kg\text{-}m/sec^2$. But it is inconvenient to say "kilogram meters per second per second," so you merely invent a new name for this unit. That's exactly what we did. We called $kg\text{-}m/sec^2$ by the name of newton.

NOTEBOOK ENTRY
Lesson 8

Under the last example entered, write: A newton has the dimensions of $kg\text{-}m/sec^2$.

Try another problem. If an unbalanced force of 18.4 nt is applied to a 4.80 kg cart, what will be the acceleration of the cart?

(26)

A 3.83 m/sec

B 3.86 m/sec

C 3.83 m/sec^2

D 3.86 m/sec^2

YOUR ANSWER --- B

You are correct. The newton is a smaller unit of weight, than the pound, and 4.5 of them to two significant figures would balance 1 lb on a scale.

NOTEBOOK ENTRY
Lesson 8

(Item 2)

(g) The weight of an object is related to its mass as follows:
(1) For bodies close to the Earth's surface in the vicinity of latitude 40° North, $w = mg$ where w is weight, and $g = 9.80$ m/sec/sec.
(2) The weight of a body on another planet or at some distance from the Earth or at latitudes that differ markedly from 40° North is given by the relation: $w = mg'$ where g' is the acceleration due to gravity at that particular place.
Example: The weight of a 10 kg mass where $g = 9.80$ m/sec^2 is:
$w = mg = 10$ kg x 9.80 m/sec^2 = 98 newtons.
(3) There are approximately 4.5 nt in one pound. A body that weighs 98 nt would therefore weigh about 22 lb.

Here are two examples already done for you.

A certain high school student weighs 125 lb. What is his weight in newtons?

$$125 \text{ lb} \times 4.5 \text{ nt/lb} = 562.5 \text{ nt} = \underline{560 \text{ nt}} \text{ (2 sig. fig.)}$$

A heavy car weighs 22,500 nt. What is its weight in pounds?

$$\frac{22{,}500 \text{ nt}}{4.5 \text{ nt/lb}} = 22{,}500 \text{ nt} \times \frac{1 \text{ lb}}{4.5 \text{ nt}} = \underline{5{,}000 \text{ lb}}.$$

Now using what you have learned, figure this out yourself:

The moon, being a much smaller body than the Earth, has a smaller gravitational force; hence the value of g on the moon is also smaller. It is about 1/6 that of the Earth. What happens to the weight of an object on the moon?

(31)

A It will weigh less on the moon than on Earth.
B It will weigh the same on the moon as on Earth.
C It will weigh more on the moon than on Earth.

YOUR ANSWER --- B

You are correct. If you hit this right off, you are to be congratulated!

In this problem, you should keep in mind the fact that the entire system is in equilibrium. (Refer to Figure 14 on page 96). It doesn't matter whether B is tied to A, or whether we consider B tied directly to the ceiling through A. If 8 nt of force act downward on the B spring, it will stretch until the balance indicator reads 8 nt. So much for Balance B.

Since B is weightless, we can consider it merely as a connecting link, like another short length of string between the weight and Balance A. Such a link will communicate the 8 nt of force to Balance A just as though Balance B were not there at all. Hence, Balance A will also indicate an 8-nt force.

We can view it another way. Go back to Balance B. A downward force of 8 nt acts on its spring; the spring stretches until it exerts an upward reaction force of 8 nt to maintain equilibrium. Now for Balance A. It is supporting the 8-nt weight and Balance B, but since the latter is weightless, it "feels" a downward pull of only 8 nt. Its spring reacts with an upward reaction force of 8 nt, too. Thus, total equilibrium is maintained, and both balances read 8 nt.

Please turn to page 147 in the blue appendix.

You have now completed the study portion of Lesson 8 and your Study Guide Computer Card and A V Computer Card should be properly punched in accordance with your performance in this Lesson.

You should now proceed to complete your homework reading and problem assignment. The problem solutions must be clearly written out on 8½" x 11" ruled, white paper, and then submitted with your name, date, and identification number. Your instructor will grade your problem work in terms of an objective preselected scale on a Problem Evaluation Computer Card and add this result to your computer profile.

You are eligible for the Post Test for this Lesson only after your homework problem solutions have been submitted. You may then request the Post Test which is to be answered on a Post Test Computer Card.

Upon completion of the Post Test, you may prepare for the next Lesson by requesting the appropriate

1. study guide
2. program control matrix
3. set of computer cards for the lesson
4. audio tape

If films or other visual aids are needed for this lesson, you will be so informed when you reach the point where they are required. Requisition these aids as you reach them.

Good Luck!

YOUR ANSWER --- A

You are correct. As illustrated in Figure 4, your velocity without benefit of the strap would be maintained in the same direction due to inertia while the bus swung toward the right. Hence, you would have fallen from one of the windows on the left side, or the outside of the curve.

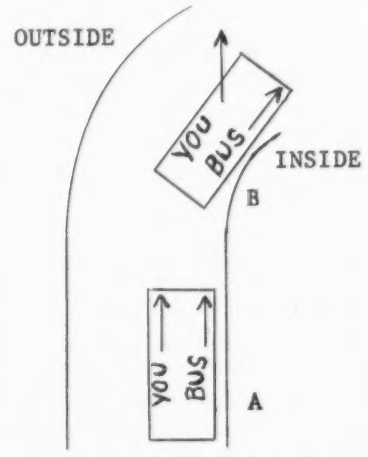


Figure 4

It is of great importance that you recognize a certain fact now, and forever keep it in mind. Many high school students are under the impression that a force acts on a revolving body to compel it outward. This inertia effect is what has been called "centrifugal force." THERE IS NO SUCH FORCE. When your body tends to fly toward the outside of a curve, THERE IS NO FORCE PULLING IT IN THAT DIRECTION. Inertia is not a force; it is not a push or pull. Inertia does not tend to change the motion of a body as does a true force. In actual fact, inertia acts to prevent a change of motion, so that if the body is in motion, inertia tends to keep it that way.

A body moving in a curve tends to fly outward only because matter possesses the property of _____. (What's the word?)

Please turn to page 141.

YOUR ANSWER --- C

You haven't looked hard or long enough.

Try multiplying each figure in the a column by 5. Then compare each product with its accompanying member in the F column.

Do you now see that a relationship does exist? We hope so.

Please return to page 72. Select the correct answer.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- B

Refer to Figure 4. Your velocity at A and the velocity of the bus at the same point are shown by vector line segments of equal length in the same direction. Your velocity at this time is identical with that of the bus.

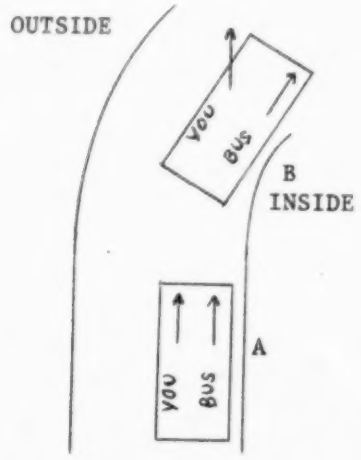


Figure 4

At position B, your velocity is the same as it was previously, but the velocity of the bus has altered: its speed is the same, but its direction is different.

If you hadn't held the strap, you would have kept moving with the same speed in the same straight line according to the Law of Inertia. Notice the direction of the "you" vector at position B.

If you could fit through one of the windows of the bus, on which side (outside or inside?) would you have left the vehicle?

You know the answer now. Please return to page 121.

YOUR ANSWER --- A

It is not entirely correct.

Following our usual practice, we will not tell you how many are wrong but will point out only one error which is enough to invalidate the group. But this does not mean that all the other answers in the group are correct.

There is an error in the answer to question number 3. Question 3 requires that you find the unbalanced force. Force cannot be measured in kilograms.

Please return to page 97 and carefully check over the other two groups by comparing them with your own answers.

YOUR ANSWER --- A

Your answer is incorrect.

You need to check over your notes on proportions once again. Please do this before you attempt to answer the next question.

Say that, from an examination of a table such as the one shown here you suspect the existence of a direct proportion between two variables.

mass	acceleration
m	a
2m	a/2
3m	a/3
6m	a/6
9m	a/9

What test should you apply to determine whether a direct proportion exists?

(16)

A Using successive pairs of values, see whether there is a constant ratio between them.

B Using successive pairs of values, see whether there is a constant product obtained.

YOUR ANSWER --- B

This answer contains two errors. Both the numerical portion and the unit are wrong.

Please do it again more carefully. Return to page 56 and select a better answer.

YOUR ANSWER --- C

The answer you selected shows signs of very cautious thinking, but it also shows neglect of the facts.

You are trying to take the weights of the balances into account despite the fact that you were told to assume that they have no weight. If the balances are weightless and identical to each other, their readings will be exactly the same. We'll prove this later, but we want you to think through this problem again, making use of all the laws and facts at your command. What kind of reaction forces will be acting on the spring balances?

Please return to page 96 and try again.

YOUR ANSWER --- C

You are correct. A rough sheet of paper may introduce more friction that is desirable between the ball or egg and its surface. When you jerk the paper out, some of your force may be transferred to the object. This would cause it to move horizontally and miss the tumbler. This may also happen if you pull the paper too slowly.

Whenever you ride in a bus or railroad train, you undergo the effects of inertia, particularly if you happen to be standing.

You have just entered a stationary bus. You are at rest with respect to the bus and the bus is at rest with respect to the ground. The driver now presses his accelerator pedal causing the bus to go into motion, say toward the north. Inertia tends to keep your entire body at rest, but there is a substantial force applied to the soles of your shoes due to the friction between them and the rough floor. Since the bus is accelerating toward the north, your feet are dragged along in the same direction. The rest of your body, however, tends to remain at rest with respect to the ground. So unless you are holding on to a strap or bar with your hand, your feet will be pulled out from under you.

In which direction would you fall?

(5)

A Toward the south.

B Toward the north.

YOUR ANSWER --- B

You are correct. Referring to the weight as Body A and the spring as Body B, then Body A exerts a force of 5 nt on Body B. Body B then reacts by exerting a 5-nt force on Body A. Thus, the spring pulls back on the string with a reaction force which, by means of the pulley, can then exert an upward force of 5 nt on the weight. That explains why the weight remains in equilibrium despite the force of gravity.

How about this one? A man stands in a rowboat a few feet from shore, facing east. On the shore is a post. He lassoes the post with a rope, then jerks the end of the rope toward his body, thereby exerting a force toward the west. Nevertheless, the rowboat starts moving toward the east, in toward shore. How can this be?

All of the statements below have the ring of truth, but only one answers this question. Which one is it?

(40)

A The reaction force of the post on the man and boat is directed toward the east; hence the boat must move to the east if it is free to move at all.

B The man facing east pulls himself toward the east by exerting a westerly force on the post.

C Since the man pulls toward the west, Newton's Third Law makes him move toward the east.

YOUR ANSWER --- C

You are correct.

We are now going to state a proposition. We will not give a formal proof for it because the proof is difficult and not worth the time and space it would require. Instead, we will show the validity of the proposition under actual "working conditions." Here it is.

If a given quantity q is separately proportional to b and also to c, then q is also proportional to the product of b and c. That is:

If $q = kb$,
and also $q = kc$,
then $q = kcb$.

Now we wonder if you can perform this stunt with Newton's Second Law. As a hint, let q be the acceleration (a), let b be the unbalanced force (F), and let c be the reciprocal of the mass (1/m). Using the proposition discussed above, put these quantities together to form a single proportion relating a, F, and m. Try it before looking at any of the answers; then choose the one you think is correct.

(19)

A $a = kFm$

B $a = F/m$

C $a = kF/m$

YOUR ANSWER --- B

We don't like this answer.

Our objection to it is based on a rather fine point of expression. If anything is to move toward the east, man or boat, then an easterly force must be exerted on it. The acceleration of any body always occurs in the direction of the unbalanced force applied to it. (Newton's Second Law.)

The answer you chose states that the man exerts a westerly force on the post. If, when he does so, the post were pulled out of the ground, then the post would move toward the west. It's motion would be accounted for by the force exerted by the man since both would be in the same direction.

But we want to know what causes the man to move toward the east. Surely, there must be an easterly force acting on him.

Please return to page 69. There is a better answer that you can choose.

YOUR ANSWER --- A

That is not true.

To straighten you out on this, we'll have to go back to our method of determining whether a proportionality exists, and if it does, what kind of proportionality it is.

To illustrate, we'll choose some figures and construct a table. (These figures are perfectly legitimate, incidentally.) Suppose that when $F = 2$ lb, we measure an acceleration $a = 0.4$ ft/sec^2. When we double the force to 4 lb, the acceleration doubles to 0.8 ft/sec^2, and so on. We can arrange these figures in a table like this:

F(lb)	a(ft/sec^2)
2	0.4
4	0.8
6	1.2
8	1.6
10	2.0

Now, you must remember that we test for proportionality by seeing whether, using the data in the table, we can obtain either a constant ratio, or a constant product, or no constant relationship at all.

Try it for yourself. Which one of the answers below do you see in the table above?

(13)

A A constant product.

B A constant ratio.

C No relationship.

YOUR ANSWER --- A

You are correct. Regardless of the mass of the body, if air resistance is neglected, it will accelerate at 9.80 m/sec^2. (Review your notes for Lesson 6, particularly item 3(b)(1).) This figure is valid only near the surface of the Earth and at latitudes in and around 40^o North. You will also recall that acceleration due to gravity is symbolized by g rather than by a.

So, we have these two facts: (1) the force due to gravity exerted on an object is given by its weight; hence $w = F$; (2) acceleration due to gravity is g which, in MKS units, is 9.80 m/sec^2. We may, therefore, replace a in $F = ma$ with g.

Substituting w for F and g for a, we can write:

$$w = mg$$

Now let's investigate the implications of this statement: the weight of an object is equal to its mass times gravitational acceleration. This statement is true whether or not the body is in motion; that is, the weight of a stationary body is given by this product even though g stands for acceleration, a process usually associated with motion. Admittedly, this concept is not a simple one. If you are a bit puzzled, now be patient because we are sure things will be clarified for you as we go along.

In MKS units, if the mass is measured in kilograms and g is measured in meters/second/second, what unit MUST the weight come out in?

(29)

A Pounds.

B Kilograms.

C Newtons.

YOUR ANSWER --- B

You are correct. The correct solution follows:

Step 1: Determine m_1. $m_1 = F/a_1 = \frac{5 \text{ nt}}{8 \text{ m/sec}^2} = 5/8 \text{ kg}$

Step 2: Determine m_2. $m_2 = F/a_2 = \frac{5 \text{ nt}}{24 \text{ m/sec}^2} = 5/24 \text{ kg}$

Step 3: Add the masses to find the combined mass.

$$\frac{5}{8} \text{ kg} + \frac{5}{24} \text{ kg} = \frac{20}{24} \text{ kg}$$

Step 4: Determine the acceleration of the combined mass when acted on by a 5-nt force.

$$a = \frac{F}{m} = \frac{5 \text{ nt}}{\frac{20}{24}\text{kg}} = 5 \text{ nt} \times \frac{24}{20} \text{ kg} = 6 \text{ m/sec}^2$$

One more problem before we go on to Newton's Third Law. No hints this time! You're on your own, so take care!

Two forces act on the same particle at right angles to each other. One force is 8.0 nt to the east; the other is 6.0 nt to the north. If the particle is at rest at the time the forces are applied, and its mass is 2.5 kg, then:

(a) In what direction will it accelerate? State the direction in terms of an angle to the north of east.

(b) What will be the magnitude of its acceleration?

After you have completed the problem, turn to page 92.

YOUR ANSWER --- A

No, this is not right.

A bit of reflection may remind you that we never measured weight in the MKS system in any of our previous work. Weight is the force of gravitation acting on a body.

In finding resultants and equilibrants, when resolving forces into components what unit did we use consistently? It was the pound, was it not?

Perhaps your confusion arises from your recollection that a kilogram of matter weighs about 2.2 lb. This is quite correct, but you are misinterpreting it. One kilogram of matter exerts a weight of about 2.2 lb, but the weight is being measured in pounds, not in kilograms.

We must therefore return to the question. What does the kilogram, as a unit, measure?

Please return to page 19 and select another answer.

YOUR ANSWER --- A

We must think carefully here. We know that the boy applies the force, so we must count him as one body. Now, suppose the rope is just lying loose on the ground not connected to anything. Suppose, furthermore, that the rope is absolutely weightless. In that case, the force needed to move the rope would be so insignificant that it could be discounted. Certainly, the force required to move the rope alone is very different in magnitude from that required to move both the rope and the box.

We find this to be true in every situation involving the application of a force. That body which applies the force must be considered as only one of the bodies in the action; that to which the initial force is applied must be taken into account as a second body. Unless we do this, we cannot fully describe the events which occur as the result of the application of the force.

Please return to page 29 and choose the alternative answer.

YOUR ANSWER --- A

You are correct. The soles of your shoes move north, and your body stays at rest with respect to the ground; hence it will seem to you that you are falling toward the south.

Now the bus is in uniform motion. It is moving along a smooth straight road with constant speed. You find that you can release the strap and move around just as confortably as you could in a stationary vehicle; you can walk forward or back, or to either side, with no adverse effects.

Which one of the statements below best explains why this is possible?

(6)

A Your body is in dynamic equilibrium with respect to the bus and is therefore experiencing no unbalanced forces.

B Your body is being kept in motion by the force exerted on you by the floor of the bus; hence any forces you exert will move you just where you want to go.

C Your body is in dynamic equilibrium with respect to the ground and is not experiencing any unbalanced forces.

YOUR ANSWER --- A

This is right.

Then if you found a constant product rather than a constant ratio, what kind of proportionality would you know existed?

Now you will go back to the original question and test the series of values for mass and acceleration given there for both constant ratio and for constant product. Then you will be able to select the right answer with no difficulty.

Please return to page 142.

YOUR ANSWER --- A

You are correct. If there is no motion of your body, your body is not accelerating. But any unbalanced force will cause acceleration; hence there can be no unbalanced force acting on your body.

Where then, does the force that "balances" the weight of your body have its origin? Almost without thinking you could say that the chair must push upward with a force that is exactly equal and opposite to the weight of your body. And you would be right.

From other evidence of a similar nature, Newton concluded that forces always come in pairs; you cannot, under any conditions, exert a force without bringing into existence a second force that has the same magnitude but is directed oppositely.

It is at this point that students of physics frequently make a serious, damaging blunder. It arises usually from an incomplete statement of the Third Law that may still be found in otherwise reliable textbooks. It is sometimes called the "law of action and reaction." Here's another incomplete statement:

"For every force, there is an equal and opposite force." You must have heard this statement before, probably in junior high school science. Another way of phrasing it is this:

"Every action has an equal and opposite _____."

What's the missing word? Do you know?

Please turn to page 102 for the correct answer.

YOUR ANSWER --- B

You are correct. If each pair of associated values is multiplied, you find that the table yields a constant product, indicating that an inverse proportion exists between acceleration and mass.

Let's phrase it this way: for a constant unbalanced force, the acceleration of a body is inversely proportional to the mass of the body.

We now have this relationship plus the one obtained previously, namely, that the acceleration of a body is directly proportional to the unbalanced force if the mass remains constant.

We wrote the last statement in our familiar shorthand:

$$a = kF$$

to show that a is directly proportional to F, if m is constant.

Now how can we write the inverse proportion in the same kind of shorthand? In other words, which two of the expressions below are correct?

(1) $a = k$ (3) $ma = k$

(2) $a = k/m$ (4) $a = m/k$

Select the right answer from the choices below.

(17)

A (1) and (2) are correct.

B (2) and (3) are correct.

C (3) and (4) are correct.

D (1) and (4) are correct.

YOUR ANSWER --- B

The statement is: "For every force there is an equal and opposite force."

The forces are oppositely directed according to the statement. If this is the case, then the arrows must be pointing in opposite directions, just as we have shown them in Figure 9 on page 102.

Please return to page 102. Choose the answer that really points out the error.

YOUR ANSWER --- A

When you divide 9.9 nt by 2.2 lb, you obtain 4.45 nt/lb, which to two significant figures, is 4.5 nt/lb. We read this as "4.5 newtons per pound" or "4.5 newtons in each pound."

This cannot be read as "4.5 lb in 1 newton," of course. There are several newtons in one pound; hence, the newton is a smaller unit than the pound.

Please return to page 109 and choose the other answer.

YOUR ANSWER --- C

This is incorrect.

The expression is:

$$1 \text{ m/sec}^2 = k \times \frac{1 \text{ nt}}{1 \text{ kg}}$$

Since we wish to determine the numerical value of k, we shall ignore the units for the moment and work only with the numbers. So we have:

$$1 = k \times \frac{1}{1}$$

Now using the rules of elementary algebra, you can solve this for k in a flash!

Please return to page 88. You can select the right answer.

YOUR ANSWER --- A

The arrows in the diagram have been made equal in length to show that the forces are equal in magnitude. This part is right.

Certainly, if the boy pulls on the box with enough force, the box should move toward him; hence his force on the box must be directed toward the left in the drawing; on the other hand, if the boy pulled hard enough and if the box didn't move, he would be drawn toward the box. This shows that the force on the boy is directed toward the right. Thus the two forces are in opposite directions.

So in what way is the statement above untrue?

Please return to page 54 and choose a better answer.

CORRECT ANSWER: A particle moving with constant velocity is in dynamic equilibrium.

We repeat, just once more for extra emphasis, that if a body is moving with constant speed in a straight line, there can be no unbalanced force acting on it.

Add to your notes: in parentheses after 1(a)--(static equilibrium). And in parentheses after 1(b)--(dynamic equilibrium).

Before continuing, please turn to page 143 in the blue appendix.

Figure 2 shows the arrangement of a simple little experiment you can perform at home. It illustrates inertia of rest quite clearly. A sheet of stiff notebook paper is laid on a heavy glass tumbler. A marble, ping-pong ball, golf ball, or, if you have the courage, a raw egg rests on the paper directly over the middle of the tumbler's mouth. Grasp the upturned edge of the paper firmly and then pull it out from under the ball (or egg) with a very sudden, horizontal jerk. If you use an egg, be sure the tumbler is filled 3/4 of the way with water to cushion the fall as the egg drops into the glass.

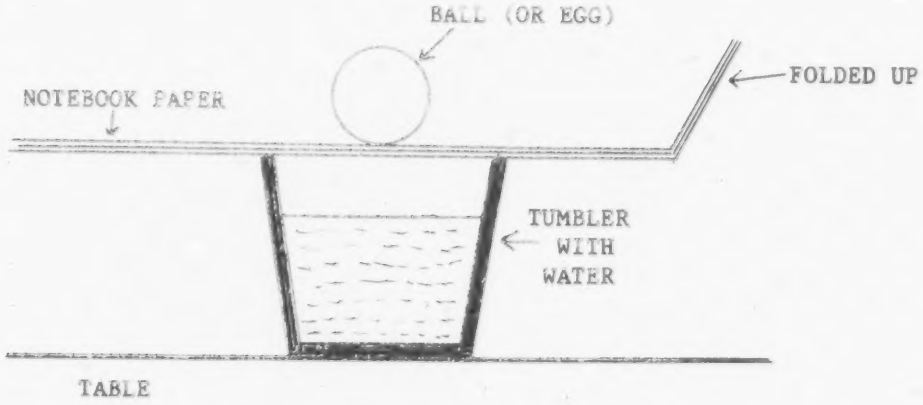


Figure 2

Why might this experiment fail to work?

(4)

A If the notebook paper is too smooth.

B If the notebook paper is too stiff.

C If the notebook paper is too rough.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- A

The statement is perfectly right as far as it goes, but it is not the best answer in the group.

If you have made the plane too massive--too much wood, the wrong kind of wood, too much fabric, etc.--you would have to increase the strength and twist of the rubber band to an impracticable extent. Attempting to obtain enough force to accelerate this poorly designed plane adequately might result in excess tension in the rubber band and consequent collapse of the structure.

Since Newton's Second Law involves TWO factors, both of which play equally important roles in determining acceleration, then you need to account in your design for both.

Please return to page 115 and select a better answer.

CORRECT ANSWER: If a force of 1 nt is applied to a body of 1 kg mass, the acceleration will be 1 m/sec^2.

To help you appreciate the effect of defining a unit based upon the proportion used to express the Second Law, we'll write the proportion once again:

$$a = k\frac{F}{m}$$

The symbol k represents a constant, but we have no numerical value for it yet. Without knowing the value of k, we cannot use the proportion as an equation for determining a, F, or m because even if two of the three variables were known, it would still contain two unknowns. But by defining the newton of force as we did, an interesting thing happens.

$$\text{From } a = k\frac{F}{m}$$

$$\text{we can get } 1 \text{ m/sec}^2 = k \times \frac{1 \text{ nt}}{1 \text{ kg}}$$

It is clear that we obtained the second expression by substituting quantities whose relationships are established by the definition of the newton. That is, if the unbalanced force is 1 nt, and it acts on a 1 kg mass, then the acceleration by definition must be 1 m/sec^2.

Now look at the second expression as an equation in which k is the unknown. If you solve for k now, what numerical value must it have?

(22)

A The numerical value of k is zero.

B The numerical value of k is unity or 1.

C The numerical value cannot be determined by solving the expression for k.

YOUR ANSWER --- B

That can't be!

As indicated in your notebook entry, the weight of a given object anywhere is given by the form of Newton's Second Law which reads:

$$w = mg'$$

where g' = acceleration due to gravity at that particular place.

On the moon, g' is about 1/6 g. Thus, $g' = \frac{1}{6} \times 9.8 \text{ m/sec}^2$ which is about 1.6 m/sec^2.

If you use w = mg', the weight of the object on the moon is:

$$w_m = m \times 1.6 \text{ m/sec}^2$$

whereas the weight of the same object on the Earth is:

$$w_e = m \times 9.8 \text{ m/sec}^2$$

Since the mass of an object does not change regardless of location, m has the same value in both statements. Your answer choice is obviously incorrect, isn't it?

Please return to page 57. You can do better on your next selection.

YOUR ANSWER --- B

This is incorrect.

Please return to page 106 and select another answer.

YOUR ANSWER --- A

You can't get a constant product out of this set of figures. Look at this:

$2 \times 0.4 = 0.8$
$4 \times 0.8 = 3.2$
$6 \times 1.2 = 7.2$
and so on.

Certainly 0.8 is not the same number as 3.2; and 3.2 is not the same as 7.2. Only if multiplying the figures in this way kept giving you the same answer could you say that the table of data indicates the existence of a constant product.

Please return to page 72. Select another answer.

Step 1: Draw the diagram. From this (Figure 8), you can see that you are dealing with a 3:4:5 triangle.

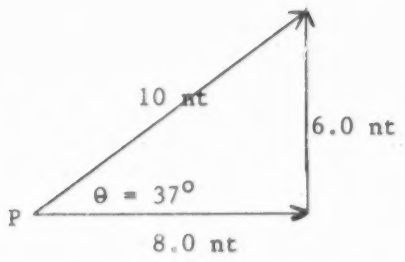


Figure 8

Step 2: The resultant force acting on the particle is 10 nt.

Step 3: If your background includes trigonometry, you can obtain the angle between the resultant and the 8.0-nt force from $\sin \theta = 0.6$, or $\theta = \sin^{-1} 0.6$. If not, you must draw the diagram to scale and measure the angle. To 2 significant figures, the angle $\underline{\theta = 37^{\circ}}$.

Step 4: The acceleration of the particle due to the resultant is:

$$a = \frac{F}{m} = \frac{10 \text{ nt}}{2.5 \text{ kg}} = \underline{4.0 \text{ m/sec}^2}$$

Newton's Third Law describes a characteristic of nature which is familiar to all of us. Actually, the reason behind most phenomena involving the Third Law is so simple and obvious that until Newton, nobody bothered to state it formally. It is a tribute to Newton's genius that he recognized the need for expressing in quantitative terms the explanation for even such elementary events.

Please turn to page 146 in the blue appendix.

An illustration of the Third Law is before your eyes this very minute. The weight of your body is 125 lb, arbitrarily speaking. This means that the gravitational force pulling your body downward toward the center of the Earth is approximately 560 newtons.

The Second Law has taught us that an unbalanced force causes the body it acts upon to accelerate in the direction of the force. Yet your body is at rest with respect to the chair on which it rests and to other objects in the room.

How can this be? Here is a force of 560 nt acting on your body, tending to pull it downward, tending to accelerate it toward the Earth's center. Why doesn't it move?

One of the statements below contains the essentials of the correct explanation. Read them all carefully. Don't look for "tricks." We are not trying to trap you with words, but, obviously, rigorous reasoning requires the choice of precise words that mean what they say. Which statement do you choose?

(35)

A Despite the fact that 560 nt of force are acting downward on your body, there is no unbalanced force acting on it.

B Your body has a large mass. Since acceleration is inversely proportional to mass, the force of 560 nt is simply not large enough to produce motion.

C Gravitation cannot act through the material of the chair, just as light cannot pass through a solid sheet of steel or wood.

YOUR ANSWER --- C

The boat in which the man stands can be accelerated toward the shore only by a force, not by a natural law!

Oh certainly, we know what you mean. But you must say exactly what you mean. Don't be satisfied with statements that sound "fancy" but have no real "meat" in them. All scientific study involves a discipline of our thought; our words must say exactly what we mean.

As we said, a mass is accelerated by an unbalanced force. You cannot say that Newton's Third Law does anything besides attempt to describe some of the events in our universe.

There is a much better way to explain the man's motion.

Please return to page 69. Find the best statement.

YOUR ANSWER --- C

The incorrect part of this answer has to do with the direction of motion.

The engine of a car does not "lift" the car, but it does make it move. A lifting force, if large enough, will cause matter to move upward, but other forces can produce downward or sideways motion.

You must try to avoid a careless use of words because it leads to equally careless thinking. The language of physics is precise; a word should never be used in any other sense than the one for which it was intended.

So return to page 4 please, and choose a better answer.

YOUR ANSWER --- A

You are correct. The man (Body A) exerts a force toward the west on the post (Body B). The post reacts by exerting a force toward the east on the man, according to the Third Law. This force is unbalanced; hence the man and boat move toward the shore.

We have one more tricky little problem for you before you complete this lesson.

We want you to imagine that you have two weightless spring balances; both are quite accurate. You hang one from the ceiling (see Figure 14), the second to the hook of the first, and an 8-nt weight on the hook of the lower balance.

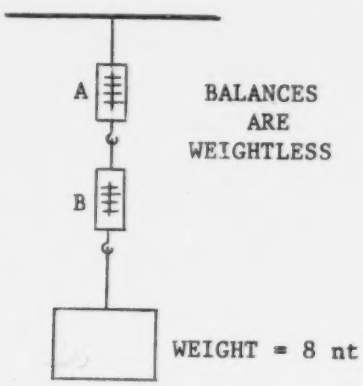


Figure 14

Now don't jump to conclusions! Think! Make use of your knowledge of equilibrium and Newton's Laws. What will each of the balances read in newtons?

(41)

A The balances will read 4 nt each.

B The balances will read 8 nt each.

C Balance A will read slightly more than 4 nt, while Balance B will read about 5 nt.

YOUR ANSWER --- C

You are correct. Substituting in $a = F/m$, we may write:

$$a = \frac{18.4 \text{ nt}}{4.80 \text{ kg}} = 3.83 \text{ m/sec}^2$$

To do a unit check on this result, you would have to substitute kg-m/sec^2 for newtons thus:

$$\frac{\frac{\text{kg-m}}{\text{sec}^2}}{\text{kg}} = \text{m/sec}^2$$

It is important that you practice manipulation of the Second Law equation. Work out each of the problems below to two significant figures. Be sure to copy all the data for each problem on your paper.

1. $F = 30$ nt; $a = 10$ m/sec^2; find the mass.

2. $m = 5.2 \times 10^{-2}$ kg; $a = 1.1 \times 10^2$ m/sec^2; find the unbalanced force.

3. acceleration $= 1.5 \times 10^3$ cm/sec^2; mass $= 1.0 \times 10^3$ grams; find the unbalanced force.

4. $m = 12$ kg; $F = 144$ kg-m/sec^2; find the acceleration.

5. A mass of 10 kg starts from rest and is accelerated steadily by a constant force of 5.0 nt acting for 8 sec. What velocity does the mass acquire at the end of the interval?

Select the only group below in which <u>all</u> of the answers are correct.

(27)

Group 1	Group 2	Group 3
1. 3.0 kg	1. 0.33 kg	1. 3.0 kg
2. 5.72 nt	2. 5.72×10^6 nt	2. 5.72 nt
3. 1.5 kg	3. 1.5 nt	3. 1.5 nt
4. 12 m/sec^2	4. 12 m/sec	4. 12 m/sec^2
5. 0.5 m/sec^2	5. 4.0 m/sec	5. 4.0 m/sec

A All the answers in Group 1 are correct.

B All the answers in Group 2 are correct.

C All the answers in Group 3 are correct.

YOUR ANSWER --- C

You are correct. The minus sign shows that the applied force must oppose the motion of the spaceship; it must, therefore, be applied in the direction opposite that of the spaceship's motion.

NOTEBOOK ENTRY
Lesson 8

(Item 2)

(h) The acceleration produced by an unbalanced force acting on a mass takes place in the direction of the force. An unbalanced force acting north produces an acceleration to the north; if the unbalanced force acts 34 degrees east of south, then the acceleration will take place 34 degrees to the east of south; etc. A force applied to a moving mass in the direction of motion causes an increasing velocity or positive acceleration; a force applied to a moving mass in the direction opposite to that of the motion causes decreasing velocity or negative acceleration.

Example: The force applied by retro rockets in a space vehicle is exerted in the direction opposite to the motion; hence, it causes deceleration (negative acceleration).

To help you collect your thoughts, we'll summarize the steps in the problem just completed.

(1) We converted the 5-ton weight to a 10,000-lb weight.
(2) We converted the 10,000-lb weight to MKS units and obtained a weight of 45,000 newtons.
(3) We determined the mass of the spaceship from the weight and obtained a mass of 4,600 kg.
(4) We applied the Second Law to find the required force and obtained -4.6×10^5 newtons. We recognized that the magnitude of the force was 4.6×10^5 nt and that it was directed oppositely to the motion of the spaceship.

Please turn to page 44.

YOUR ANSWER --- A

Since force is the unknown in this problem the following form should be used:

$$F = ma$$

Now, is the answer called for to be a quotient or a product? In other words, does the problem require division or multiplication?

Look at your solution. Somehow you performed the wrong arithmetical operation.

Please return to page 107 and work the problem again.

YOUR ANSWER --- B

You are correct. The moment the force is removed, the body goes into dynamic equilibrium, (assuming the absence of all retarding forces like friction and air resistance).

Experiments show that an unbalanced force acting on a body causes it to accelerate steadily just as long as the force acts.

The cart, m, in Figure 5 (assumed frictionless) is in static equilibrium before Force F_1 is applied. The moment F_1 starts to act, the cart will begin to move to the right, gradually picking up speed. If F_1 is a constant force, the acceleration (a_1) of the cart will be uniform; that is, its speed increases at the same rate every second.

F_1 and F_2 are unbalanced applied forces

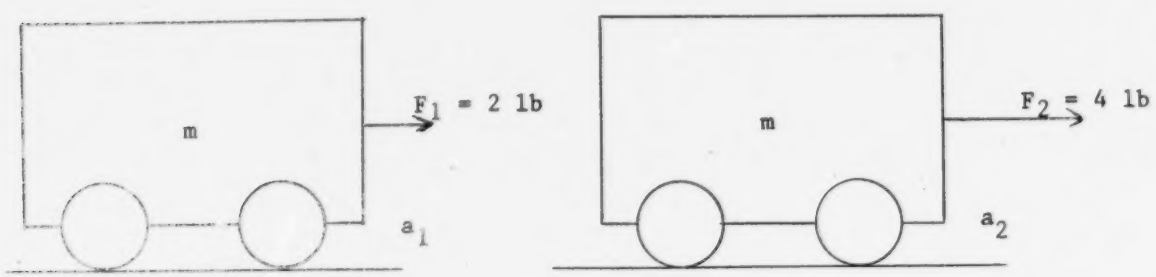


Figure 5

We will assume that F_1 is constant at all times. Continuing with the experiment, we find that if F_1 is a given value, say 2 lb, then the cart will have an acceleration a_1. Should F_1 now be doubled, say to 4 lb, what do you think will happen to the acceleration? (We mean acceleration, not velocity.)

(11)

A The acceleration will increase.

B The acceleration will decrease.

C The acceleration will remain the same.

YOUR ANSWER --- A

In choosing this answer, you simply didn't make use of your every day experiences.

What are we looking for in asking the question: "Which acceleration will be larger or will they be the same?" We merely want to know the effect of mass on acceleration.

No doubt you have had some experience with opening and closing doors. There is a kind of door called "hollow core" which has a comparatively small mass because it consists almost entirely of a front and back of thin plywood. Assuming the door has frictionless hinges, a very small unbalanced force is needed to start it moving. Old-fashioned oak doors are much more massive (forget about weights; doors move horizontally so that gravity contributes nothing to oppose the force you use to open or close them). Now if you apply the same small unbalanced force to a massive oak door, will its acceleration have the same magnitude as in the example of the hollow core door? Will the acceleration be larger or smaller?

Please return to page 137. You should be able to select the best answer now.

CORRECT ANSWER: "Every action has an equal and opposite reaction."

Both of these statements, by omitting certain significant details, become completely misleading. Let us show you why this is so.

When you say "For every force there is an equal and opposite force," you offer no information as to the body to which these two forces are applied. Refer to Figure 9.

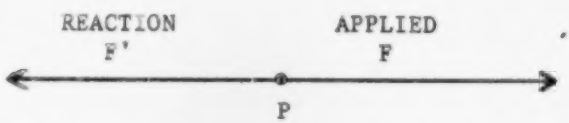


Figure 9

A force F is applied to a particle at rest. Instantly, according to the above statement of the Third Law, a "reaction" force F' springs into being. It is equal and opposite to the applied force F. Everything we've done fits the requirements of the statement. Yet see how illogical it is. Imagine that particle P is a bit of fluff with a mass of, say, 0.001 kg and that we apply to it a large force of, perhaps, 5,000 newtons to the right. Your experience tells you that such a large force applied to a small mass will produce quite a large acceleration to the right. The Second Law has demonstrated this. So, something is wrong with the picture presented in Figure 9. Which of the following statements points this out?

(36)

A F and F' are collinear; there is nothing in the statement which gives us the right to say the forces are collinear.

B The arrows in Figure 9 should be pointing in the same direction.

C Figure 9 shows balanced forces which could not cause the particle to accelerate.

YOUR ANSWER --- A

No! The arithmetic is faulty.

The expression we're working with is:

$$1 \text{ m/sec}^2 = k \times \frac{1 \text{ nt}}{1 \text{ kg}}$$

We wish to determine the numerical value of k. We will therefore ignore the units for a moment and work only with the numbers. So we have:

$$1 = k \times \frac{1}{1}$$

But since $\frac{1}{1} = 1$, the value of k cannot possibly be zero.

Please return to page 88. You can now choose the correct answer.

CORRECT ANSWER: 10,000 lb is the equivalent of 45,000 nt.

We know, then, that the spaceship weighs 45,000 nt. To use Newton's Second Law, we are going to need the mass of the spaceship. Well, we have a perfectly good equation which relates mass and weight. It is:

$$w = mg$$

The ship weighs 45,000 nt on Earth. This means that the value of g to be used in the above equation is 9.8 m/sec^2.

Fine! Now to find mass, we shall want to solve the equation for m. That is:

$$w = mg$$

$$\text{so} \quad m = \frac{w}{g}$$

You know the value of w in newtons, and you know the value of g in m/sec^2. We leave it to you to determine the mass of the ship in ____ (what unit?). Go ahead! Find the mass of the spaceship and then write your answer.

Turn to page 51 for a check on your work.

YOUR ANSWER --- B

Just exactly what do you mean by a "negative force?"

Unless this is explained, the statement above can hardly be called best, especially when applied to the original question. Merely saying that the force required to produce a deceleration of 100 m/sec^2 is -4.6×10^5 nt. does not answer the original question unless you explain the meaning of the minus sign.

So return to page 51 please. Select the answer that is <u>really</u> informative.

YOUR ANSWER --- B

You are quite correct. If you picked these on the first try, you are doing very well. The mathematical expression for an inverse proportion must show a constant product for each pair of variables. Thus, we can write it this way: $ma = k$ or this way: $a = k/m$. If the m is transposed, it becomes a numerator and the equation returns to the form $ma = k$.

We can now sum this up in a suitable notebook entry.

NOTEBOOK ENTRY
Lesson 8

2. Newton's Second Law of Motion

(a) If the mass of m of a body is held constant, then the acceleration a of the body is directly proportional to the unbalanced force, or

$$a = kF$$

(b) If the unbalanced force applied to a body is kept constant, then the acceleration a of the body is inversely proportional to its mass m, or

$$a = k/m \quad \text{(or } ma = k\text{)}$$

(c) The symbol k merely signifies a constant number. That is, the value of k in each of the above expressions is not necessarily the same. In fact, in this case, the two k's have different values.

Notebook Check

Refer to item 1(b) of this lesson. Which one of the following things does this item describe?

(18)

A A body in a state of rest.

B A body in a state of accelerated motion.

C Dynamic equilibrium.

D Static equilibrium.

YOUR ANSWER --- A

You are correct. And, of course, in this form mass must still be expressed in kilograms and acceleration in meters per second per second if F is to come out in newtons.

Before continuing, please turn to page 145 in the blue appendix.

Let's get this information into our notebooks.

NOTEBOOK ENTRY
Lesson 8

(Item 2)

(d) By combining the two proportions, we obtain a single proportion

$$a = k\frac{F}{m}$$

which reads: the acceleration of a body is directly proportional to the unbalanced force applied to it and inversely proportional to the mass of the body.

(e) The k in the proportionality may be eliminated by defining a new force unit in terms of mass and acceleration. The new force unit is called the newton (nt) and is defined as that unbalanced force which gives an acceleration of 1 m/sec^2 to a mass of 1 kg. On the basis of this definition, the k factor becomes unity or 1.

(f) Thus the two most commonly used mathematical forms of Newton's Second Law are:

$a = \frac{F}{m}$ and $F = ma$

F is in newtons (nt) if
m is in kilograms and
a is in meters/sec/sec.

A few sample problems will help fix these relationships in your mind. A block of metal resting on a table has a mass of 45 kg. In order to give it an acceleration of 3 m/sec^2 what unbalanced force is required?

(24)

A 15 nt B 135 nt

YOUR ANSWER --- A

This answer is incorrect.

In a problem of this type, it is extremely difficult for us to analyze your errors without seeing the actual work. You will have to do this for yourself when you study the correct solution. What is most important at this point, however, is that you do not give up trying to arrive at the right answer.

This problem is approached by determining the individual masses with the help of $m = F/a$.

The total combined mass is then obtained by adding the individual masses. Leave these in fractional form for convenience. Perhaps you had better check to see if you made an error in adding the fractions.

The acceleration of the combined mass is then determined by means of $a = F/m$. Remember that the only force available in this problem is 5 newtons.

Try it again. Then please return to page 44 and select the corresponding answer. DO NOT GUESS! (Science is not a game of chance).

YOUR ANSWER --- C

You are correct. Assume a body has a mass of 3.00 kg; then using the formula $w = mg$, we find its weight to be:

$$w = mg = 3.00 \text{ kg} \times 9.80 \text{ m/sec}^2 = 29.4 \text{ kg-m/sec}^2 = \underline{29.4} \text{ } \underline{\text{nt}}.$$

You are so accustomed to expressing weight in pounds that this will sound stange to you at first. Perhaps it would be advisable here to determine which is the larger weight unit, the pound or the newton, and then to find out how many of one are contained in the other. (This is not a requirement, but it will help give you a feeling for these units.)

Let's first calculate the weight in newtons of a 1 kg mass.

$$w = mg = 1 \text{ kg} \times 9.8 \text{ m/sec}^2 = 9.8 \text{ kg-m/sec}^2 = \underline{9.8} \text{ } \underline{\text{nt}}.$$

So, 1 kg of mass weighs 9.8 newtons. From the Metric-English equivalent table in your notebook, you will find that 1 kg also can be said to weigh 2.2 lb. So there is a greater number of newtons in a given mass than there are pounds; hence the newton is a smaller weight unit than the pound. To find the precise relationship, we must divide:

$$\frac{9.8 \text{ nt}}{2.2 \text{ lb}} = \frac{\text{nt}}{\text{lb}}$$

Thus, which one of the following is a true statement?

(30)

A There are 4.5 lb in 1 newton.

B There are 4.5 nt in 1 pound.

YOUR ANSWER --- A

You are correct. Mass, not speed, governs the amount of inertia possessed by a body at rest or a body in motion.

We know enough about inertia now to state the so-called Law of Inertia in formal terms. This law is also frequently called Newton's First Law of Motion.

NOTEBOOK ENTRY
Lesson 8

1. Newton's First Law of Motion (The Law of Inertia.)

   (a) A body at rest tends to remain at rest unless acted upon by an unbalanced force.

   (b) A body in motion tends to remain in motion with unchanging speed and direction (constant velocity) unless acted upon by an unbalanced force.

Both portions of Newton's First Law of Motion should have a very familiar ring to you. These same ideas were discussed when we studied equilibrium.

A particle is in static equilibrium when it is at rest because, if it were acted upon by an unbalanced force, it could not remain in equilibrium; it would begin to move in the direction of the unbalanced force. So we might say that a body is in static equilibrium as a consequence of the First Law.

We also discovered in our work with equilibrium, that a particle moving with constant velocity must also be free of unbalanced forces because, were one or more of such forces present, the particle would have to change its speed or direction. What kind of equilibrium is this?

Please turn to page 85 to see.

YOUR ANSWER --- B

This may be true in some cases, but it certainly is not <u>necessarily</u> true all the time.

For example, when you buy a 5-cent chocolate bar, you expect it to contain a certain amount of "matter." Should you decide on a <u>larger</u> bar, you expect that it will have enough additional "matter" to make the extra cost worthwhile. For chocolate bars, then, the larger the bar is the more likely it is to contain more matter.

But compare the quantity of matter in a large sponge, say, 2" x 4" x 6", with the quantity of matter in a comparatively small ingot of coin silver. While the ingot is only 1" x 1" x 1" in size, it contains a good deal more matter than the sponge, even if you add the air "matter" that permeates the sponge's pores.

So, you see, the size does not necessarily indicate how much matter a body contains.

Please return to page 131 and select a better answer.

YOUR ANSWER --- B

The stiffness of the paper should not affect the results.

Of course, if the paper is stiff, you might have to be more careful in placing the ball or egg over the mouth of the tumbler; these rounded objects might roll off if the supporting sheet is perfectly horizontal. A less stiff paper tends to sag a bit under the object, forming a kind of cup that holds it in place.

But, if you are careful, stiff paper will work just as well.

Please return to page 85 and select another answer.

YOUR ANSWER --- A

If you can borrow a pair of balances from your physics teacher, you ought to try this little experiment. Of course, the balances you use will not be weightless, but when you see what happens, you can easily imagine what would have occurred if they actually were weightless.

Right now, it will have to suffice to say that they will not read 4 nt each, nor will their readings be close to this value. The explanation will appear with the correct answer.

Don't guess at your next answer choice. Do a little more hard thinking. What kind of reaction forces will be acting on the spring balances?

Please return to page 96 and try again.

YOUR ANSWER --- C

You are correct. We hope you arrived here on the first try. The proposition as applied to the Second Law works this way:

$$a = kF$$

and $a = k/m;$

so $a = k(F \times \frac{1}{m})$

or $a = k\frac{F}{m}.$

Verbally, this statement reads: the acceleration of a body is directly proportional to the unbalanced force applied to it and inversely proportional to the mass of the body.

We'd like to see how you would interpret this in one or two real-life situations.

Please go on to page115.

Most boys and many girls have flown model airplanes powered by a twisted rubber band which whirls the propeller. This type of plane must accelerate very quickly if it is to take off at all. Suppose you built one and found that it worked all right in every respect except one: it wouldn't take off from the ground. Which one of the following would you consider as the best procedure to follow in accomplishing your objective?

(20)

A Increase the force exerted by the propeller; use a stronger rubber band.

B Decrease the force exerted by the propeller, but increase the mass of the plane to give it better stability.

C Decrease the mass of the plane by removing some unneeded wood and increase the force exerted by the propeller.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- B

No; the kilogram is a mass unit. The weight of the object cannot be expressed in the same unit because weight and mass are entirely different quantities.

Yes, we know that laboratory weights are often marked in kilograms. These should be called laboratory masses to be strictly correct. To add to the confusion, these laboratory weights are often marked 1.00 kgw, 1.50 kgw, etc. The kgw unit means kilogram-weight and is not the same as a simple kilogram.

For the novice in physics, it is better to forget about such things as gmw and kgw completely. You may, when you have acquired a degree of sophistication in physics, want to go back to these units. That's fine, but not for now!

In our lessons, we shall continue to confine the kilogram to mass and mass only.

O.K. Then, what is the weight unit in the MKS system?

Please return to page 73. You should be able to choose the right answer now.

YOUR ANSWER --- B

No, we don't mean this at all.

A body that weighs 5 tons on Earth will weigh 5/6 ton on the moon and it will weigh practically nothing at all out in deep space where stars and planets are so faraway from it that their gravitational effects are negligible.

The mass of a given body is constant regardless of where it happens to be located; but weight varies widely depending on location.

The spaceship, then, cannot have a weight of 5 tons everywhere in the universe.

Please return to page 27 and make another choice.

YOUR ANSWER --- A

The statement is: "For every force there is an equal and opposite force."

What does the word opposite mean when applied to forces? All along, we have used it to signify the direction of a force exerted along the same line as another force and at an angle of 180^{o} to it. But when two forces act at 180^{o} to each other, they are collinear; hence we had every right to draw the forces as we did in Figure 9 on page 102.

We have drawn the forces according to our interpretation of the statement. They should be shown as collinear if they are oppositely directed.

Please return to page 102. Find the statement which <u>really</u> points out the error.

YOUR ANSWER --- A

There's a mixup of terms here!

You and the bus are moving at exactly the same constant speed in a straight line. Hence, with respect to the bus, your body is motionless. You can easily read the advertising signs above the seats of the bus because you are at rest with respect to them.

So, with respect to the bus, your body is in a state of static equilibrium. The answer above is unacceptable.

Please return to page 77. Pick a better answer.

YOUR ANSWER --- B

You are correct. When an object moves in a curved path, its direction changes continuously. Since velocity is a vector quantity, if the path curves, direction changes, and the vector changes. It is very important to remember at all times that although a body may have a constant speed it might not have a constant velocity.

Returning to Figure 3 on page 17, now imagine yourself inside the bus as it moves from B to C. Review item 2(b) for this lesson in your notebook. Your body, being an object of substantial mass, tries very hard to follow Newton's First Law. Its inertia tends to keep it moving with the same speed and in the same direction. Hence, as the bus changes direction toward the east, your body attempts to keep moving north. Obviously, you have to remain inside the bus at this juncture! You don't want to go flying out a window! So, you grab for the strap to prevent your body from following its natural tendency to keep moving north. This action compels your body to follow the changing direction of the bus.

If you hadn't held the strap, which window might you have flown from? (Assuming that it was large enough to accommodate you.)

(8)

A One of the windows on the left side, toward the outside of the curve.

B One of the windows on the right side, toward the inside of the curve.

YOUR ANSWER --- C

You are correct. The significant difference between this statement and our previous conception which resulted in vectors that cancel, is that here the initial force and the reaction force are applied to different bodies. With different points of application, the forces are no longer considered concurrent and cannot be added algebraically or vectorially. In other words, one force acts on one body and the other acts on the second body. What each body will do depends on the surrounding conditions. If the friction between the box and the floor is small, then the force applied by the boy on the box will accelerate the box toward him; should the friction between the boy's shoes and the floor be smaller than the friction between the box and floor, then the force applied by the box on the boy will accelerate him toward it. If the friction is very great in both cases, neither body will move despite the application of the pair of forces.

Let us now state Newton's Third Law in its most useful form.

NOTEBOOK ENTRY
Lesson 8

3. Newton's Third Law of Motion

(a) When Body A applies a force to Body B, Body B reacts by applying a force equal in magnitude but opposite in direction to Body A.

(b) Note that the applied force and the reaction force act on two different bodies.

Please turn to page 128.

YOUR ANSWER --- A

The ton is directly related to the English pound by the ratio: 2,000 lb/ton. In our work, the pound is taken strictly as a force unit, not as a mass unit. The ton, therefore, must be considered in the same strict sense as a unit of force.

For this reason, when we specify a 5-ton spaceship, we do not mean that its mass is 10,000 lb.

On the basis of this explanation, you should have little difficulty in choosing the right answer.

Please return to page 27 and make another selection.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- A

You are correct, of course.

A body in dynamic equilibrium moves with uniform velocity because there are no unbalanced forces acting on it to change either its speed or its direction.

Please return to the original question on page 141.

YOUR ANSWER --- C

Does this answer correspond with your experience? Perhaps you chose it because you have forgotten the exact meaning of acceleration.

Acceleration is the rate of change of velocity with respect to time. Remember? $a = \Delta v/\Delta t$. Think back to the last time you pulled someone along on a sled or wagon. If you wanted to get the sled up to high speed in a hurry, didn't you dig in with your toes and pull on the rope for all you were worth? Well, "getting the sled up to high speed in a hurry" is an offhand way of saying that you were causing a large acceleration.

But at other times when you didn't particularly care what the acceleration of the sled turned out to be, you didn't have to pull nearly so hard to get the sled moving.

So you can't really believe that different forces on the same body will produce the same acceleration.

Please return to page 100. The best answer ought to be obvious to you now.

YOUR ANSWER --- B

It is not entirely correct.

As usual, we will follow the practice of informing you of only one error, which is enough to invalidate the whole group. However, there may be other errors besides the one we point out.

There is an error in question number 1. The unit is correct, but the number is wrong. You must have somehow inverted the equation to have arrived at m = 0.33 kg.

Please return to page 97. Remember to select the group in which all the answers are correct.

To extend your understanding of the Third Law, we'll investigate one or two other special cases. Refer to Figure 13.

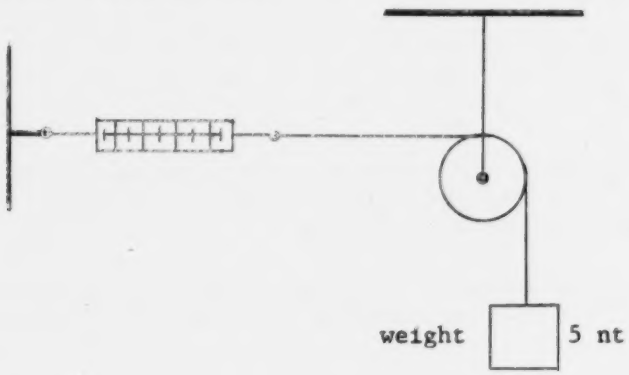


Figure 13

A force of 5 newtons is applied to a spring balance via a string and pulley. (The spring balance is to be considered weightless.) You will surely agree that the balance will read 5 newtons if it is accurate. We can say, without much danger of argument, that the applied force is the 5 nt due to the weight acting on the spring of the balance, causing it to become extended.

According to the Third Law, we must assume the presence of a second force. Which of the following statements best describes this second force?

(39)

A The second force has a magnitude of 5 nt and acts downward on the 5-nt weight.

B The second force has a magnitude of 5 nt and acts upward on the 5-nt weight, thereby maintaining equilibrium.

C The second force has a magnitude slightly more than 5 nt and acts to the right on the wall supporting the balance.

YOUR ANSWER --- B

What happened to the constant k?

You will see that in the proposition as originally given, the constant is retained throughout.

If $q = kb$
and $q = kc$,
then $q = kcb$.

As we have said before, k represents a constant, although not the same constant as we go from one form to another. But a constant k does appear in the final form.

Go back and check your work. Find out where you inadvertently dropped the constant.

Then return to page 70 and choose the right answer.

This page has been inserted to maintain continuity of text. It is not intended to convey lesson information.

YOUR ANSWER --- B

You are correct. This answer is precise and accurately descriptive. The heavy Program Control Device is matter at rest relative to the table top. Since the Earth is moving, this is just as much a state of motion as anything else. If the machine were to change its position relative to the Earth, this would constitute a change of motion.

If, at this very moment, the force of gravitation acts upon the machine, why does it not move downward? An unbalanced force is required to change the state of motion, so the force of gravitation must be balanced out by another force. The table top must be exerting an equal force upward on the machine--equal, that is, to the weight of the Program Control device. We shall have more to say about such balancing forces later in this lesson.

All of this points to a universal principle. Before we state this principle in conventional language, however, it is most essential that we clarify some of our terms. Any real particle, body, or object is made of matter. At the beginning of our course, we defined mass tentatively as the quantity of matter in a particle, body, or object.

As a qualitative start then, which of these is most accurate?

(2)

A The greater the space occupied by a body, the greater its mass must be.

B The larger a body is, the more matter it must contain.

C As the amount of matter in a body increases, its mass increases.

YOUR ANSWER --- A

No, your answer is not correct.

Here we have a weight of 5 nt to start. The force of gravitation is acting downward on the weight with a force of 5 nt. Now if a second force of 5 nt is applied on top of this also acting downward, the total downward force would be 10 nt. Since you have not provided for any upward force on the weight at all, then the 10 nt would be unbalanced, and the weight would fall with accelerated motion. It does not do so, however, as you can gather from the very conditions picture in Figure 13 on page 128.

Thus your answer does not fit the facts.

Please return to page 128 and choose another answer.

YOUR ANSWER --- B

You are quite right. Quantity of matter or resistance to change of motion (inertia) is measured in kilograms in the MKS system.

Now let's go back to Newton's Second Law: $a = kF/m$. In the MKS system, acceleration is measured in meters per second per second or m/sec^2; in the MKS system mass is measured in kilograms. But, you see, we do not yet have a unit for force.

Because Newton's laws of motion are so fundamental in mechanics, physicists long ago decided to define the unit of force by using the Second Law as given above. Refer to Figure 7.

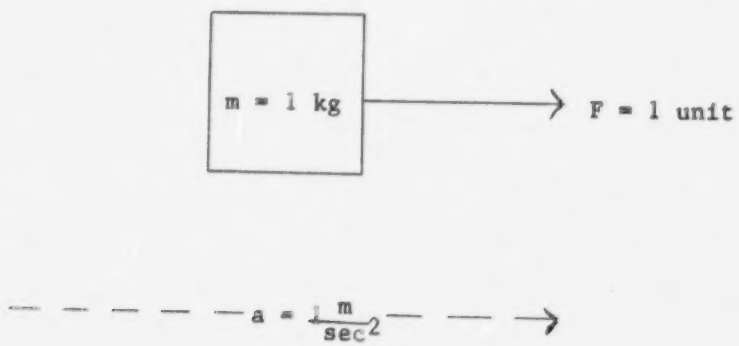


Figure 7

They reasoned something like this: "Let's take 1 kg of mass and apply a force to it such that the acceleration of this mass will be 1 m/sec^2. We will then call this unit of force by a special name. Well, what shall we call it?"

The name of the force unit finally selected was called quite appropriately the newton, abbreviated nt. So one of the greatest physicists who ever lived has been eternally honored by having a unit named after him.

So now, if 1 newton, or 1 nt, of force is applied to a body whose mass is 1 kg, what will be its acceleration?

Keep your answer in mind as you turn to page 88.

YOUR ANSWER --- A

Your answer consists of three sentences. The first sentence is absolutely correct; Units must check. The second and third sentences are not correct, however.

We obtained the newton as a unit of force by defining it in terms of mass and acceleration. This means that if the mass is given in the unit contained in the definition, namely kilograms, and if the acceleration is given in the unit contained in the definition, namely meters per second per second, then the answer must come out in newtons when substitution is made in $F = ma$.

We must conclude that the answer given in newtons has been given in the right unit. But we also know that units must always check. Hence, there can be only one possible answer.

Please return to page 48 and select the correct answer.

YOUR ANSWER --- C

Well, let's see.

The weight of a body anywhere is given by this form of Newton's Second Law:

$$w = mg'$$

where g' = the acceleration due to gravity at that location.

You are told that g' is about 1/6 g. Hence $g' = \frac{1}{6} \times 9.8 \text{ m/sec}^2$.

Thus, $g' = 1.6 \text{ m/sec}^2$ approximately.

So, if $w = mg'$, then the weight on the moon would be:

$$w_m = m \times 1.6 \text{ m/sec}^2$$

whereas the weight on Earth would be:

$$w_e = m \times 9.8 \text{ m/sec}^2.$$

Since the mass of a body does not change regardless of location, m has the same value in both statements. So your answer is obviously wrong.

You can do better. Please return to page 57 and choose the right answer.

YOUR ANSWER --- B

This is what we would call specious reasoning. The statement may "sound good", but it is based on false premises.

It is quite true that acceleration is inversely proportional to mass, but let us not forget that it is also directly proportional to force. Look at the formula below:

$$a = \frac{F}{m}$$

The acceleration can be zero only if (a) the unbalanced force is zero, giving us a zero numerator in the fraction F/m; or (b) the mass is <u>infinite</u>, causing the fraction to be zero.

Now, the mass of your body is certainly not infinite. If your body weighs 560 nt, then the mass is approximately:

$$m = \frac{w}{g} = \frac{560 \text{ nt}}{9.8 \text{ m/sec}^2} = 57.2 \text{ kg}$$

Then there can be only one other answer to the question of the immobility of your body despite the 560-nt force acting on it. Could the chair be exerting a force on your body?

You should be able to select the logical answer. Please return to page 93.

YOUR ANSWER --- B

You are correct. If F doubles, a doubles; if F triples, a triples; etc. This implies a constant ratio which is positive identification of a direct proportion.

Then, since acceleration is directly proportional to unbalanced force, we may write:

$$a = kF$$

where k is some constant of proportionality.

Note: acceleration and force are both vector quantities. To be strictly correct in writing this relationship, we ought to add the vector arrows thus:

$$\vec{a} = k\vec{F}$$

To avoid this constant repetition, it will be acceptable at this time to omit the arrows, but always remember that we are dealing with vectors.

What else affects the acceleration of a body besides the unbalanced force? You can get a strong hint from Figure 6.

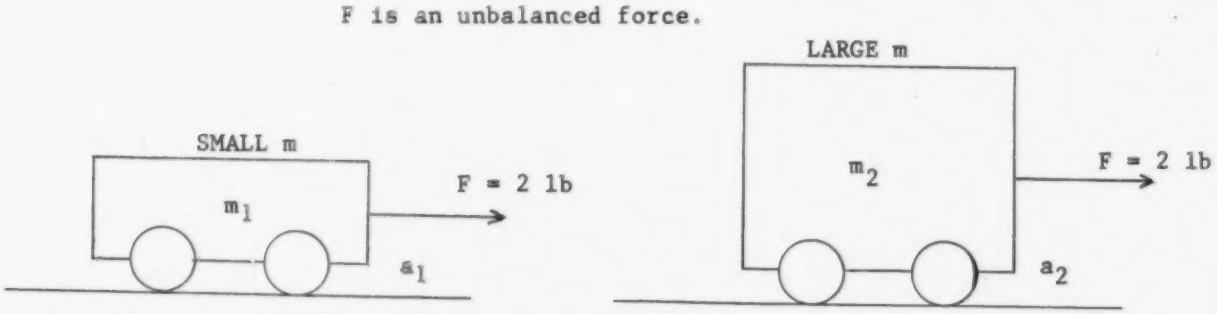


Figure 6

Noting that the same unbalanced force F is applied to both frictionless carts, which of the following would you say is true?

(14)

A a_1 is the same magnitude as a_2.

B a_1 is larger than a_2 in magnitude.

C a_1 is smaller than a_2 in magnitude.

YOUR ANSWER --- A

Watch your units. Acceleration is not measured in m/sec.

Please return to page 56 and choose another answer.

YOUR ANSWER --- C

There is an error in your algebra.

Starting with $a = F/m$, you want the factor F alone to appear on one side of the equation.

You could solve for F simply by multiplying both sides of the equation by m. Try it. Once you get F alone on the right, you can exchange it with the expression on the left and so get F on the left.

Please return to page 10. Choose the correct form of the equation solved for F.

YOUR ANSWER --- A

Did you notice that we didn't ask you to select the correct answer? All of the statements are correct but only one of them is really informative with respect to the original question.

As the answer above states, the magnitude of the force is 4.6×10^5 nt. This is quite correct. It is all right to call the force a "minus quantity" because the numeral is prefixed by a minus sign. But what does that mean? What is a "minus force?" What does it tell you?

Please return to page 51 and make another selection.

CORRECT ANSWER: A body moving in a curve tends to fly outward only because matter possesses the property of inertia.

NOTEBOOK ENTRY
Lesson 8

(Item 1(b))

Examples of inertia of motion:

(1) A passenger in a moving train tends to fall forward as the train slows down or stops suddenly.

(2) If the train accelerates suddenly, the passenger tends to fall backward.

(3) If the train rounds a curve, the passenger tends to fall toward the outside of the curve. This effect is due entirely to the action of inertia which tends to keep the passenger moving in a straight line. THERE IS NO FORCE ACTING ON THE PASSENGER TO CAUSE HIM TO MOVE OUTWARD.

Before continuing, please turn to page 144 in the blue appendix.

We proceed now to some quantitative thinking about this matter of inertia. Throughout the discussion that follows, when we refer to a body on which a force acts, you are to assume the complete absence of friction, air resistance, or any other kind of retarding force, unless we specifically mention one. To keep things simple, any force we apply to a particle or body should be thought of as a horizontal force so that we won't have to worry about the effects of gravity. (Gravitational force acts vertically and cannot affect horizontal motion because it has no horizontal component.) We'll remind you of these assumptions at the beginning, but we must depend on you to remember them after that.

When we apply an unbalanced force to a body at rest, the body must begin to move. That is, it must accelerate in the direction of the force. If this force is applied for a moment or two and then removed, what will the body do?

(9)

A It will continue to accelerate.

B It will continue to move with constant velocity.

YOUR ANSWER --- B

You are correct. A very small unbalanced force applied to a ping-pong ball may give it tremendous acceleration, while the same force applied to a bowling ball would hardly change its motion at all. Again, if the forces are horizontal, weight has nothing to do with the effect because gravitational force has no horizontal component. Hence it can neither assist nor hinder horizontal motion. So, it is mass we are concerned with, not weight.

Laboratory measurements (for the kind of example shown in Figure 6 on page 137) show that if m_2 is twice m_1, then a_2 will be half as large as a_1, provided that the force F remains constant in both cases. Similarly, if m_2 is three times as large as m_1, then a_2 will be one-third as great as a_1, again with F constant. There is a proportion here: as m becomes larger, a becomes proportionately smaller if F remains constant. Without using numbers or units, we could write the following table based upon experiment:

If the mass is m, then the acceleration is a;
If the mass is 2m, then the acceleration is a/2;
If the mass is 3m, then the acceleration is a/3;
If the mass is 6m, then the acceleration is a/6;
If the mass is 9m, then the acceleration is a/9; etc., etc.

What relationship is implied by these results?

(15)

A A direct proportion.

B An inverse proportion.

WORKSHEET

Please listen to Tape Segment 1 of Lesson 8 before starting to answer the questions below. Use Computer Card for answers.

1. Regarding the four objects described in the inertia experiment, which one of the four statements below is most correct? The object that would be the most difficult to leave behind so that it would fall into the tumbler is

   A the marble because it is much smaller than the other objects.
   B the ping pong ball because it has so little mass.
   C the golf ball because it has a pocked surface.
   D the raw egg because it is liquid-filled.

2. To perform a similar experiment with long-stemmed wine glasses on a tablecloth as some waiters are reputed to be able to do, you would have to be sure that

   A theglasses were weighted so that the onlookers couldn't see the weight.
   B the tablecloth is pulled out firmly but slowly.
   C the tablecloth has an almost friction-free surface.
   D the glasses had roughened bottoms.
   E there were no more than three glasses on the cloth at the time the experiment is done.

3. If someone were to jerk a rug out from under you, you would probably topple over. The best reason for the tendency to topple is that

   A the mass of your body is not concentrated in a point.
   B your body has too much mass for this experiment to work.
   C your body has too little mass for this experiment to work.
   D there is a great deal of friction between your shoes and the rub.
   E there is very little friction between your shoes and the rug.

Please return now to page 85 of the STUDY GUIDE.

WORKSHEET

Please listen to Tape Segment 2 of Lesson 8 before starting to answer the questions below. You will also need to view the brief film entitled INERTIAL FORCES - CENTRIPETAL ACCELERATION as directed in the tape.

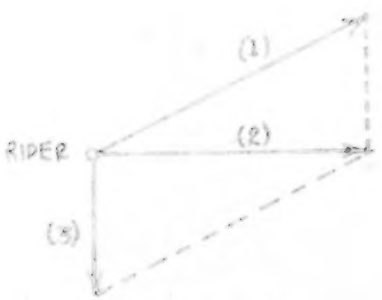
4. With regard to a passenger riding in a fast train as it rounds a curve, which of the following statements is WRONG?

   A There is no force acting outward on the passenger.
   B He slides outward because of his body's inertia.
   C He is subjected to an outward force due to rotation.
   D He is subjected to an inward force as long as he remains in the train.
   E The train is subjected to an inward force supplied by the rails.

5. The fixed frame of reference used for most our laboratory experiments in physics is

   A the Earth.
   B the Sun.
   C the Moon.
   D the North Star.
   E any one of the visible stars.

6. The vector diagram below correctly shows the forces that act on a rider in the ROTOR as seen by an observer on the outside. One of the numbered forces is that of the wall acting on the rider; another is the force which keeps the rider moving in a circle; and finally the other is the weight of the rider. Select the group which correctly identifies the forces according to number.



   A (1) inward force on rider.
     (2) wall on rider.
     (3) weight of rider.

   B (1) wall on rider.
     (2) weight of rider.
     (3) inward force on rider.

   C (1) weight of rider.
     (2) inward force on rider.
     (3) wall on rider

   D (1) wall on rider.
     (2) inward force on rider.
     (3) weight of rider.

Please return to page 141 of the STUDY GUIDE.

WORKSHEET

Please listen to Tape Segment 3 before starting to answer the questions below.

There are no DATA ITEMS for this tape segment. Continue to indicate your answer selections on the Computer Card.

QUESTIONS

7. According to the tape discussion, the form of Newton's Second Law written this way: $a = F/m$ is a realistic way to write it because

   A acceleration is the independent variable.
   B both F and m are dependent variables.
   C both acceleration and mass are independent variables.
   D neither mass nor force is an independent variable.
   E both force and mass are independent variables.

8. By properly rewriting the Second Law, one can see that mass may be defined as

   A acceleration per unit force.
   B force times acceleration.
   C force per unit acceleration.
   D the quantity of matter in a body.
   E none of these is correct.

9. According to the tape discussion,

   A the statement $F = ma$ is incorrect.
   B the statement $F = ma$ is just as correct as $a = F/m$.
   C the statement $F = ma$ and $a = m/F$ are equally correct.
   D acceleration is inversely proportional to force.
   E acceleration is directly proportional to mass.

Please return to page 107 of the STUDY GUIDE.

WORKSHEET

Please listen to Tape Segment 4 before starting to answer the questions below.

DATA ITEM A: Equation 1: true weight = $w = mg$

Equation 2: apparent weight = $w - F_a = mg'$

QUESTIONS

10. For a falling body that has attained its terminal velocity, the value of g' is

A small.
B zero.
C negative.
D equal to g.
E large.

11. At its terminal velocity, the speed of the falling body is

A constant.
B necessarily very small.
C zero.
D necessarily very large.
E variable with time.

12. At its terminal velocity,

A the falling body is in dynamic equilibrium, having reached a speed at which the resultant of all forces acting on it is zero.

B the acceleration of the falling body is positive but of small magnitude.

C the acceleration of the falling body changes sign.
D the time required to fall a given distance is the same as it would be in a vacuum.
E the time required to fall a given distance is less than it would be in a vacuum.

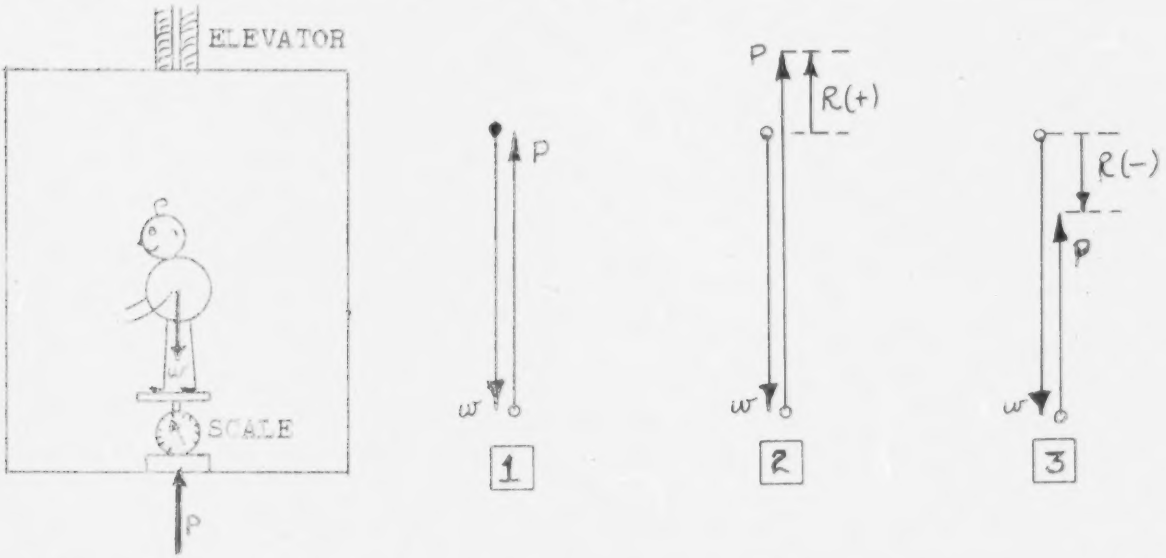
13. As the density of the fluid through which a body falls increases, its terminal velocity

A increases.
B decreases.
C remains the same.
D changes in an unpredictable manner.
E first increases, then decreases.

Please return to page 93 in the STUDY GUIDE.

WORKSHEET

Please listen to Tape Segment 5 before starting work. You will also need to view the brief film entitled INERTIAL FORCES - TRANSLATIONAL ACCELERATION as directed on the audio tape.



DATA ITEM A: The three kinds of motion executed by the elevator in its round trip as demonstrated in the film are shown pictorially in the diagrams above. As you can see, the weight w of the passenger remains constant (about 160 lb) at all times. The push of the scale platform on the passenger's feet is represented by the vector P in all diagrams. According to Newton's Third Law, the reaction to this push is the reading of the scale as the passenger (and you) see it. The unbalanced force, where it exists, acting on the passenger is the resultant R.

For each of the descriptions of motion given below, select one of the above diagrams as descriptive of this motion. If you choose diagram 1, select answer A; diagram 2, answer B; and diagram 3, answer C; if none of the diagrams fit a description, select answer D.

C 14. Just starting on the "down" trip.
C 15. At rest.
B 16. Bringing the elevator to rest at the end of the "down" trip.
C 17. Bringing the elevator to rest at the end of the "up" trip.
A 18. Just starting on the "up" trip.
19. Descending with uniform speed.
20. Ascending with constant speed.

Please return to page 59 of the STUDY GUIDE.

AMP LESSON 8

HOMEWORK PROBLEMS

1. A force of 10 nt acts upon a 2-kg mass. What is the acceleration imparted to the mass by this force?

2. What is the weight of a 10-kg piece of iron in newtons?

3. An electron is accelerated uniformly from rest to a speed of 4.0×10^{6} m/sec in 2 sec. If the mass of the electron is 9.1×10^{-31} kg, what force must have been applied to produce this acceleration?

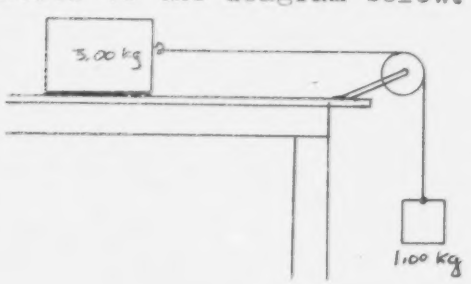
4. A force of 5 nt is applied to a body horizontally. The body rests on a frictionless surface, and accelerates at 0.4 m/sec^2 as a result of this force. What is the mass of the body?

5. A rocket has a mass of 1000 kg. What force in excess of the weight of this rocket is required to accelerate it upward at 4 ft/sec^2? Also, what is the total force acting on the rocket under these conditions?

6. A 1500-kg car starting from rest is accelerated by a force of 2000 nt during the first 15 sec of its motion. What will be the speed of the car at the end of this interval?

7. What force must be exerted on a proton whose mass is 1.7×10^{-27} kg moving at a speed of 5.0×10^{7} m/sec to bring it to rest in a distance of 1/4 meter?

8. Refer to the diagram below. Assuming that the friction between the table and the 3.00 kg block is zero and that there is no friction in the pulley, determine the acceleration of the falling block. (Hint: although only one block supplies the needed force, both blocks must be accelerated.)



9. A 160-lb man is standing on a scale in an elevator that is accelerating upward at 3.00 m/sec^2.

   (a) Find the weight of the man in newtons.
   (b) Find the mass of the man in kilograms.
   (c) What will the scale read all through the interval of this acceleration?